GEOLOGIC MAP OF WASHINGTON - SOUTHWEST QUADRANT

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TIMOTHY J. WALSH, MICHAEL A. KOROSEC,
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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-34

1987

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Brian Boyle - Commissioner of Public Lands
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Mount St. Helens, March 25, 1987. View from the north; Mount Hood (Oregon) in the background. Washington Department of Transportation photo.

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PREFACE

State geologic maps are a valuable resource for education, planning, mineral and energy exploration, and evaluation of geologic hazards. Providing up-to-date statewide geologic mapping to the public is one of the most important functions of our state geological survey.

Previous geologic maps of Washington were published in 1936 by the Division of Geology (Culver, 1936) and in 1961 by the Division of Mines and Geology (Huntting and others, 1961), both at a scale of 1:500,000. When we began planning for the new state geologic map in 1982, the first of these maps was no longer available and the second was soon to be out of print. Not only were state geologic maps becoming unavailable, but, since the last map was compiled, the plate tectonic theory had caused a revolution in geologic thinking. The fact that more than 60 percent of all Washington geologic maps had been published after 1960 further emphasized the need for a new state map. Now (September 1987) 71 percent of the 927 published and thesis maps on Washington postdate the 1961 state map. The wealth of new geologic data was also an important factor in our decision to publish the new state geologic map at the expanded scale of 1:250,000.

This map is the first of four quadrant maps which, together, will present the geology of the entire state of Washington. Work on the northeast quadrant is under way. The southeast and northwest quadrants will follow in that order. We plan to have all the quadrants available by 1993.

As noted in the section titled Map Compilation, the geology portrayed on this map was first compiled at a scale of 1:100,000. We chose to compile at that scale in order to establish a statewide map base that could preserve most of the detail of 1:24,000- and 1:62,500-scale source maps while, at the same time, consolidating the source maps to achieve a more regional view.

In order to acquire geologic mapping in unmapped or inadequately mapped areas and to substantiate geologic interpretations, the Division instituted a program to fund geologic mapping by graduate students and professors and established budgets for age dating and geochemistry. Since the 1984 field season we have supported 36 graduate students and professors statewide, and in the southwest quadrant we have acquired 32 potassium-argon (K-Ar) dates, 2 radiocarbon dates, and 253 whole-rock geochemical analyses. Many of the K-Ar dates were supported by Rockwell Hanford Operations (now Westinghouse Hanford Co.) through S. P. Reidel. These data are reported, in detail, in the 1:100,000-scale open-file reports. In addition, we have entered into a COGEOMAP (COoperative GEOlogic MAPping) agreement with the U.S. Geological Survey to map the geology of the Mount Baker, Robinson Mountain, and Twisp 1:100,000-scale quadrangles in time for them to serve as source maps for the northwest quadrant of the state geologic map.

Considerable new detailed and reconnaissance geologic mapping, was done by the staff of the Division of Geology and Earth Resources in areas where no adequate geologic mapping existed. These areas are shown on Figure 5, and the geology is presented in more detail in the 1:100,000-scale open-file reports.

We have attempted to make this geologic map useful at several levels of detail and to a variety of users in the following ways: (1) by publishing the map at a larger scale than previous state geologic maps of Washington; (2) by employing time-lithologic units on the map rather than formations; (3) by portraying unconsolidated deposits in as much detail as bedrock units; (4) by using a multiple-level scheme of colors, patterns, and symbols to portray the geologic units; and (5) by providing a fuller range of supporting materials than is commonly found on state geologic maps.

The organization of colors, patterns, and symbols emphasizes the time and lithologic divisions and provides map users with increasingly detailed levels of geologic information. The first level of detail is expressed by broad color ranges that distinguish five basic rock types—Quaternary sediments, sedimentary rocks, metamorphic rocks, extrusive igneous rocks, and intrusive igneous rocks. On the second level, variations of color within each broad color range indicate age. At the third level of detail, small groups of lithologic units are distinguished by changes in types of pattern—for example, acidic, intermediate, and basic intrusive igneous rocks. The most detailed lithologic distinctions are made by changes in symbol. This scheme will enable map users to see, at a glance, broad lithologic relationships, and, on closer inspection, correlate units, make tectonic interpretations, or discern the broad aspects of geologic history across the quadrant and ultimately across the entire state.

We have tried to accommodate a variety of map users in several ways. First, where surficial units are predominant, we show the surficial geology in as much detail as the bedrock, so engineering geologists, for example, should find the map useful in more than a cursory way. Second, we used time-lithologic units rather than formations on the map to make the map easier to interpret and to allow those who are not familiar with Washington geologic names to understand and use the geologic data with a minimum of effort. Third, those who are accustomed to dealing with formational map units instead of time-lithologic units will be aided by the supporting material on **Sheet 2**: the **Descriptions of Map Units** lists named geologic units that are included in each of the time-lithologic units; the **Correlation Diagram** shows the age ranges of named units as well as time-lithologic units; and the **List of Named Units** shows the time-lithologic unit(s) into which a named unit has been placed and the geographic location of the named unit. Finally, for those seeking more detailed information, the index maps showing sources of map data (Figs. 2-6) and the **References Cited** will guide the map user back to the original geologic source maps; the 1:100,000-scale open-file reports provide more detailed geologic compilations; and the **List of Named Units** includes representative references that describe the named units.

The state geologic map program has proved to be an exceptional opportunity to assemble unified statewide geologic data bases, at both 1:100,000 and 1:250,000 scales, that are readily available to the public and the geologic community. The program has also provided a framework that will help us to both keep track of and make future geologic map data available by updating the 1:100,000-scale open-file maps as new mapping becomes available. This project has enhanced working contacts, data exchange, and mutual support between the Division of Geology and Earth Resources and university, federal, and private-sector geologists. We are proud of this map and look forward to the continuing geologic adventure of preparing the remaining three state geologic map quadrants. We hope you will realize as many benefits in the use of this map as we have in its preparation.

J. Eric Schuster and
Bonnie B. Bunning
September 30, 1987

GEOLOGIC MAP OF WASHINGTON—SOUTHWEST QUADRANT

by

Timothy J. Walsh, Michael A. Korosec, William M. Phillips,
Robert L. Logan, and Henry W. Schasse

INTRODUCTION

The Geologic Map of Washington—Southwest Quadrant is the first in a series of four maps to be published at a scale of 1:250,000 by the Washington Division of Geology and Earth Resources. The four quadrants together will comprise the third state geologic map published by the Division and its predecessors since 1936. Quadrant boundaries are 120°30′ west longitude and 47°15′ north latitude. Each of the four quadrant publications will consist of four elements: a geologic map, a sheet displaying map unit descriptions and other explanatory material, a pamphlet of supporting data and information, and a topographic map. The first three elements will constitute a packet; the topographic base map, constructed especially for each quadrant, will be available separately.

MAP DESIGN

Base Map

No appropriate quadrant-wide topographic base maps existed at the start of the state geologic map program. The Division chose to generate a new 1:250,000-scale base map, using as the source of data metric-contour 1:100,000-scale topographic maps recently released or in preparation by the U.S. Geological Survey. The base map for this quadrant was manually scribed from scale-stable reductions (to 1:250,000) of scale-stable 1:100,000 map separates. The control framework was a computer-generated latitude-longitude grid plotted on a Universal Transverse Mercator Projection by the U.S. Geological Survey. The base map for the southwest quadrant is available from the Division of Geology and Earth Resources as Topographic Map TM-1.

Colors, Patterns, and Symbology of the Geologic Map

Based on combined time and lithologic symbology, a color and pattern scheme was developed such that both color and pattern have time and (or) lithologic significance. An overview of this scheme is given in the **Key to Geologic Units** on Sheet 1.

Because of the prevalence of Tertiary rocks in Washington, unit symbology on the geologic map portrays each Tertiary epoch with its own symbol. We chose the symbols with the help of the editorial staff of the U.S. Geological Survey (Denver); however, the U.S. Geological Survey has not adopted a standardized set of such symbols.

In only four instances are formations indicated. These are the Crescent Formation and the Saddle Mountains, Wanapum, and Grande Ronde Basalts. Those exceptions were made because these formations are in contact with units of similar lithology and age and they would not otherwise be individually identifiable on the map. The Columbia River basalts would have become part of unit Mvb and been merged with basalts of the Cascades. The Crescent Formation and Grays River volcanic rocks, which originated on different tectonic plates, would have been indistinguishable. In these four cases, the time-lithologic symbols include a letter subscript indicating the formation name.

MAP COMPILATION

Initial compilation of the southwest quadrant map was done on modern base maps of the U.S. Geological Survey 1:100,000-scale quadrangle series. Compilation at that scale helped to develop the philosophic and stratigraphic framework for the 1:250,000-scale southwest quadrant map.

Literature review and map compilation began in 1983. Field work was done from 1983 to 1986. The 1:100,000-scale maps were individually reviewed outside the Division before being synthesized into a single quadrant, and the southwest quadrant map was again reviewed by geologists from other organizations before publication. All but the Wenatchee and Snoqualmie Pass quadrangles, which were recently released by the U.S. Geological Survey, have been placed on open-file by the Division of Geology and Earth Resources. In addition to the compilation maps, the open-file reports contain detailed supporting data pertaining to stratigraphic relations, age dates, rock geochemistry and unit descriptions.

Compilation responsibility for the 1:100,000-scale maps in the quadrant is shown on Sheet 1. Table 1 identifies compiler, area, and report number.

SUPPORTING DATA

In addition to new geologic mapping by Division geologists, compilation at the 1:100,000 scale was augmented by a program of funding for new mapping by graduate students and professors. Since its inception, the program has supported 36 student and professor mapping projects statewide, six in the southwestern part of the state.

Division funds were also budgeted for the acquisition of age dates and geochemical analyses. Additional age dates were obtained through S. P. Reidel of Rockwell Hanford Operations (now Westinghouse Hanford Company). For the southwest quadrant we have obtained 32 new potassium-

Table 1.-Compiler, quadrangle, and Division open-file report number

Compiler	Quadrangle	Open File Report Number
Korosec, M. A.	Mount Adams	87-5
Korosec, M. A.	Hood River	87-6
Logan, R. L.	South half of Shelton and south half of Copalis Beach	87-9
Logan, R. L.	Chehalis River and Westport	87-8
Phillips, W. M.	Mount St. Helens	87-4
Phillips, W. M.	Vancouver	87-10
Phillips, W. M., and Walsh, T. J.	Northwest part of Goldendale	87-13
Schasse, H. W.	Centralia	87-11
Schasse, H. W.	Mount Rainier	87-16
Walsh, T. J.	West half of Toppenish	86-3
Walsh, T. J.	West half of Yakima	86-4
Walsh, T. J.	Astoria and Ilwaco	87-2
Walsh, T. J.	South half of Tacoma	87-3

argon (K-Ar) age dates, 2 radiocarbon age dates, and 253 new whole-rock geochemical analyses.

The K-Ar dates have been published in Isochron/West (Phillips, and others, 1986) and, with the geochemical analyses, are reported in the open-file reports. New radiocarbon dates are given in Walsh (1987b).

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In addition to those mentioned on Sheet 1 and those whose reports and maps are cited, many other people contributed to the publication of this geologic map. We gratefully acknowledge their assistance. These persons and the general nature of their contributions are listed below.

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DESCRIPTIONS OF MAP UNITS

The **Descriptions of Map Units** on Sheet 2 lists the lithologies contained in each map unit in decreasing order of their abundance. The lithologic classifications used in preparing the unit descriptions follow Travis (1955) except as noted below.

Sedimentary rocks

Sandstone terminology follows Dickinson (1970) when modal compositions are known. Because all sandstones in the southwest quadrant are sub-quartzose, that distinction is not made in the unit descriptions. Sedimentary rocks are further divided into marine, continental, and nearshore. Nearshore rocks include complexly interbedded marine sediments and continental sediments bearing thick coal deposits.

Volcanic rocks

Volcanic rocks for which whole-rock geochemical data are available are classified using the International Union of Geological Sciences (IUGS) system (Le Maitre, 1984; Zanettin, 1984). Basaltic andesite was included with andesite in the map units.

Intrusive rocks

Intrusive rocks are grouped by map pattern as acidic, intermediate, or basic. Acidic rocks are granite, quartz monzonite, granodiorite, and rhyolite. Intermediate rocks are quartz diorite (including tonalite), diorite, dacite, and andesite. Basic rocks are gabbro, basalt, and diabase. Aphanitic intrusive rocks were classified in the same way as volcanic rocks when geochemical data were available.

Metamorphic rocks

Metamorphic rocks are divided into high grade and low grade based on metamorphic facies. Low-grade rocks are greenschist facies and lower; high-grade rocks are amphibolite facies and higher. Metamorphosed intrusive rocks are labeled "orthogneiss" on the map and described by their specific lithologies in the unit descriptions.

At the end of each unit description is a list of the named units that are contained in that map unit. In those instances where the map unit consists entirely of the named units listed, the words "consists of" are applied. If the map unit contains named units and other unspecified units, the word "includes" precedes the list of unit names.

Formally named formations that are included in the various lexicons published by the U.S. Geological Survey are listed without reference and with "formation" or other descriptive term capitalized. Informally named units are followed by the reference to the work that defines the unit in the sense in which we have applied it. For these rocks, "formation" or other descriptive term appears uncapitalized.

Several formations have confusing or conflicting meanings because of complicated histories of use or improper correlations. These problems and the resolutions we adopted for the map are treated individually in the 1:100,000-scale open-file reports (Table 1).

CORRELATION DIAGRAM

This diagram shows maximum estimated age ranges for the geologic map units using the best available information. Because map units are time-lithologic units, formations consisting of diverse rock types are separated into their component lithologies and portrayed in more than one map unit. For this reason, a geologic unit name may appear on more than one box in the diagram. To determine all map units under which a named unit is shown, consult the **List of Named Units**.

Map units are portrayed by colored boxes whose upper and lower margins indicate age range. Some units consist of a single formation or parts of formations; others are a combination of named and (or) unnamed units grouped by similar lithology and age. All boxes carry a map unit label (symbol). A name is also given where applicable. The next paragraphs describe some of the combinations of symbols and names used in the diagram.

Map units consisting of only unnamed time-lithologic units or of informally named individual Quaternary flows are represented by single boxes containing only the map symbol. Examples of such map units are Qa, alluvium; Ql, loess; Mvd dacite flows; and Migb, gabbro.

Map units consisting of a single named unit or part of a named unit are shown by one box labeled with the map symbol and the geologic unit name. Examples are Mm_2, the Montesano Formation; Mig, the Tatoosh pluton; and Φvr, the Ohanapecosh Formation.

Map units consisting of a combination of named and unnamed units are represented by more than one box. These boxes are contiguous or located near each other on the diagram. The boxes carry geologic names as applicable. The unnamed part of a map unit is shown as a box that has the map symbol only and is near the boxes with names. Examples are Rc, Qgp, and Miq.

Where named units are identical, the box on the diagram carries more than one name. The synonymous units are listed below:

McIntosh Formation = Stillwater Creek member of Cowlitz Formation

Cowlitz Formation = Olequa Creek Member of the Cowlitz Formation = Skookumchuck Formation

Tuffaceous rocks of Wildcat Creek = sandstone of Spencer Creek

Goble Volcanics = Hatchet Mountain Formation

Rattlesnake Creek tuff = Bumping River tuff = Stevens Ridge Formation

Grande Ronde Basalt = Depoe Bay Basalt

Frenchman Springs Member of the Wanapum Basalt = Cape Foulweather Basalt

Pomona Member of the Saddle Mountains Basalt = basalt of Pack Sack Lookout

We also use more than one name on a box where a suite of named units succeed each other stratigraphically. Such instances are listed below.

Puyallup Formation and Alderton Formation

Salmon Springs Drift, Stuck Drift, and Orting Drift

Priest Rapids, Roza, and Frenchman Springs Members of the Wanapum Basalt

Asotin, Wilbur Creek and Umatilla Members of the Saddle Mountains Basalt. Note: The Elephant Mountain and Pomona Members of the Saddle Mountains Basalt are distinct enough in age to be shown as separate boxes.

Boxes on the diagram carry more than one name where named alpine glacial units are synchronous but geographically or lithologically distinct; where local names are part of a more widespread named unit; and where local names for facies of a named unit are used. These instances are tabulated below:

Weatherwax formation, Humptulips Drift

White Salmon Drift, part of the Hayden Creek Drift, part of the Amboy Drift

Evans Creek Drift, McDonald Ridge Drift

part of the Amboy Drift, part of the Hayden Creek Drift

part of the Vashon Drift, Steilacoom Gravel

part of the Vashon Drift, Colvos Sand

Upper and lower age limits are queried where uncertain.

Where dashed lines connect two parts of a box, as for unit Mida, and where a box is extended by dashed lines, as for unit Mia, rocks of the age range encompassed by the dashed lines are not known. However, there is no geologic evidence that more closely constrains the upper and lower limits, implying the possibility that rocks may exist for these intervals. All radiometric ages fall within the colored parts of the boxes.

Because this diagram attempts to show maximum estimated age ranges over the entire quadrant, the ranges shown for some units here are not the same as those shown in the **Stratigraphic Columns**, each of which shows age relations for only a portion of the map area.

The diagram time scale is from Salvador (1985), with boundary-age modifications. Stage names and stage age ranges for benthic foraminifera, molluscs, and megaflora are modified from Armentrout (1981). These modifications consist of: (1) placing the Eocene-Oligocene boundary at 35.7 m.y.b.p. (Montanari and others, 1985); (2) dividing the Refugian Stage between the Oligocene and Eocene by placing the *Cassidulina galvinensis* zone in the Oligocene and the *Sigmomorphina schenki* zone in the Eocene (Prothero and Armentrout, 1985); (3) adjusting Galvinian and Matlockian Stage boundaries so that the Eocene-Oligocene boundary falls within the Galvinian (Prothero and Armentrout, 1985); (4) correlating the Goshen flora with the *C. galvinensis* zone, which is the upper part of the Refugian Stage and the upper part of the Galvinian Stage in the Oligocene; (5) correlating the Kummerian flora with the *S. schenki* zone of the lower Refugian Stage and lower part of the Galvinian (Wolfe, 1981) Stage, and hence placing the Kummerian flora in the Eocene; and (6) placing the Pliocene-Pleistocene boundary at 1.6 m.y.b.p. (Aguirre and Pasini, 1985).

LIST OF NAMED UNITS

The **List of Named Units** indicates those named geologic units that are included in the age-lithologic units used on the map.

The first column of the list includes formal and selected informal geologic unit names that are in current use. Some formal names, such as Satsop and Hawkins Formations, are not listed because, although they have not been formally abandoned, they are no longer used.

To the right of the names are symbols for the map units that contain each named unit. Named units comprised of diverse lithologies are represented on the map by multiple time-lithologic units.

The third column lists references in which are defining or representative descriptions of the named unit in the sense that we used it for the map. We did not give the defining reference if it has been superseded or is not readily available.

The last two columns guide users to location and approximate areal extent of each named unit. Figure 1 shows county boundaries.

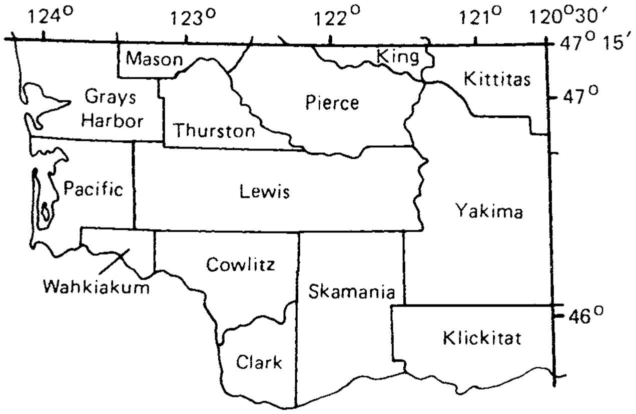

Figure 1.-Counties in southwestern Washington.

SOURCES OF MAP DATA

Figures 2 through 6 indicate the areas covered by source maps used to compile this map. Included are all maps from which linework was taken. In only one instance (Bateman, 1951) does the outlined area refer to a text, with no map, from which linework was generated. All other non-map references are noted in **References Cited**.

Source maps are arranged by scale on the figures. Original mapping done by Division geologists in the course of the state geologic map program is shown by the patterned areas on Figure 5; the results of that work are included on the 1:100,000-scale open-file maps and not referenced separately. On each figure, numbered map areas correspond to references in the accompanying abbreviated list. Full references are in the section titled **References Cited**.

STRATIGRAPHIC COLUMNS

The composite stratigraphic columns shown in the diagram on **Sheet 2** depict the stratigraphic relations of time-lithologic units used on the geologic map. Each column represents the geology of a specific geographic area, which is indicated on the small map in the lower left corner of the stratigraphic column chart.

Omitted from the columns because of diagram scale are landslide deposits, some terraced deposits, several small and poorly dated intrusive igneous units, and several volcanic units of limited areal extent in the Cascade Mountains. In addition, space limitations prohibited detailed portrayal of contacts for most Quaternary units in all columns, and for the Pliocene or Quaternary-Pliocene volcanic units in the Mount Rainier and Mount Adams-Hood River columns. Most Quaternary and Pliocene units rest unconformably on older units, but this is not shown in all columns.

The numerical time scale used on these columns permits resolution of several thousand years for the Pleistocene and Holocene units. However, absolute age ranges of most Quaternary units are poorly known, and estimates of age ranges vary widely. The apparent precision of the time scale does not imply an equally precise definition of age ranges for Quaternary units.

In the text below are the names of formations or informal units that make up the map units shown in the stratigraphic columns. In many instances, the map units do not contain any named units. Further detail about named units, including references, is given in the **List of Named Units** and **Descriptions of Map Units** on Sheet 2.

Also provided in the paragraphs below are the principal references used in constructing each stratigraphic column. The 1:100,000-scale open-file reports prepared by the Division for the southwest quadrant (Table 1) contain additional information on the age range and stratigraphic relations for map units. References to these maps are given at the beginning of each column description.

Stratigraphic units are addressed in order of increasing age. Intrusive igneous rock units are discussed following the stratified units.

Column 1—Astoria and Ilwaco 1:100,000-scale Quadrangles

See Walsh (1987a) for further stratigraphic details.

Qa — Assumed to be entirely of Holocene age.

Qb — Assumed to be entirely of Holocene age. Wiedeman (1984, p. 8-9) suggests most dune deposits are of Holocene age.

Qoa — Uncertain age range. Late Pleistocene age is suggested by dissected character of terraced deposits.

Qt — Age range, based on amino-acid racemization date for shell deposits at Willapa Bay, is from 120,000 ± 40,000 yr to 190,000 ± 40,000 yr (Kvenvolden and others, 1979).

Mv_s — Consists of the Pomona Member of the Saddle Mountains Basalt. Unit has yielded K-Ar ages of about 12 m.y. (McKee and others, 1977) in the Columbia Basin. Contact relations are from Armentrout and others (1983).

Mv_w — Consists of the Frenchman Springs Member of the Wanapum Basalt. Outside the column area, average K-Ar age of unit is 15.3 m.y. (Beeson and others, 1985). Contact relations are from Armentrout and others (1983).

Mv_g — Consists of the R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt (Wells and Simpson, 1987). Age of Grande Ronde flows is bracketed between 17.0 and 15.5 m.y. by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area (Reidel and others, 1987). Contact relations are from Armentrout and others (1983).

Mm_1 — Consists of the Astoria Formation. Age range of lower member is based on benthic foraminifera referable to the Saucesian Stage (Wells, 1981); contact relations are from Armentrout and others (1983). Age range for the upper member is based in part on relations with flows of the Columbia River Basalt Group; the upper member lies above unit Mv_w and below unit Mv_s. From regional correlations, W. W. Rau and T. J. Walsh interpret the upper member to be contained within the Relizian Stage rather than the Mohnian Stage shown in Armentrout and others (1983).

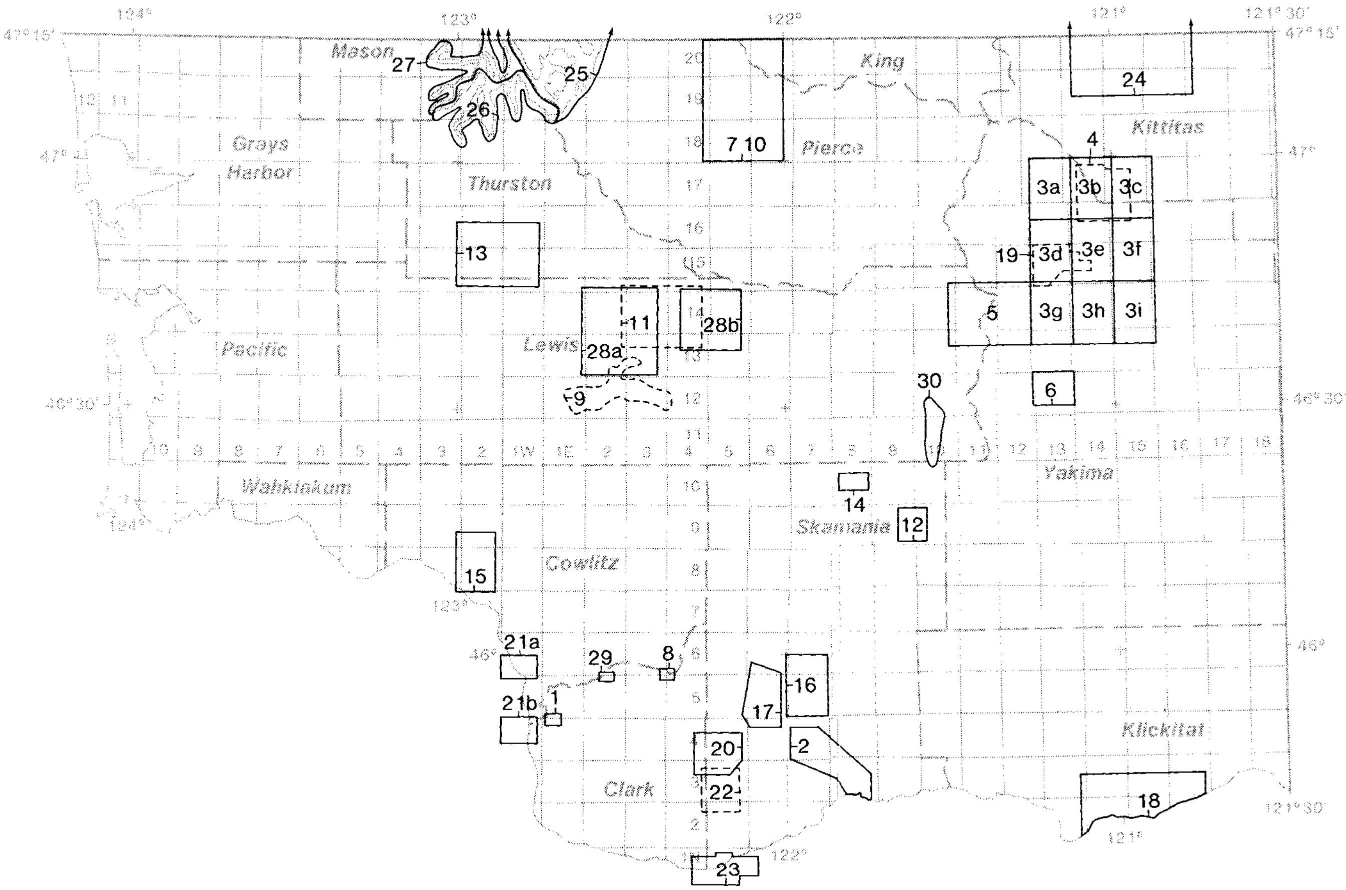

Figure 2.-Index to sources of map data, scales 1:1,200 through 1:24,000 and source references without maps.

1. Bateman, 1951 (no map with this reference)
2. Berri and Korosec, 1983; plate 1, scale 1:24,000
3. Campbell, in press (all quadrangles at 1:24,000)
   - a, Old Scab Mountain quadrangle
   - b, Cliffdell quadrangle
   - c, Manastash Lake quadrangle
   - d, Timberwolf Mountain quadrangle
   - e, Meeks Table quadrangle
   - f, Nile quadrangle
   - g, Rimrock Lake quadrangle
   - h, Tieton Basin quadrangle
   - i, Weddle Canyon quadrangle
4. Carkin, 1985; plate, scale 1:24,000
5. Clayton, 1983; plate, scale 1:24,000
6. G. A. Clayton and others, University of Washington, 1985, written commun.; scale 1:24,000
7. Crandell, 1963; plate 1, scale 1:24,000
8. Ebasco Services Incorporated, 1974; plate 4, scale 1:4,800
9. Erdman and Bateman, 1951; figure 2, scale 1:24,000
10. Gard, 1968; plate 1, scale 1:24,000
11. Hagen, 1987; scale 1:24,000
12. Harle, 1974; plate 1, scale 1:24,000
13. Lea, 1984; maps 1 and 2, scale 1:24,000
14. Link, 1985; plate 1, scale 1:12,000
15. Livingston, 1966; figure 2, scale 1:24,000
16. McGowan, 1985; plate 3, scale 1:24,000
17. Polivka, 1984; plate 1, scale 1:24,000
18. Powell, 1982; plates 1-4, scale 1:24,000
19. Schreiber, 1981; plate, scale 1:24,000
20. Schriener, 1978; plate 1, scale 1:24,000
21. Shannon and Wilson, 1968
   - a, figure II-2, scale 1:24,000
   - b, figure III-2, scale 1:24,000
22. Shepard, 1980; plate 1, scale 1:24,000
23. Tolan, 1982; plate, scale 1:21,120
24. Walker, 1980; map 1A, scale 1:24,000
25. Washington Department of Ecology, 1979; scale 1:24,000
26. Washington Department of Ecology, 1980a; scale 1:24,000
27. Washington Department of Ecology, 1980b; scale 1:24,000
28. Weyerhaeuser Company, 1979, unpublished data
   - a, 1 plate
   - b, 1 plate
29. Williams, 1930; plate 148-18, scale 1:1,200
30. Winters, 1984; plate 1a, scale 1:24,000

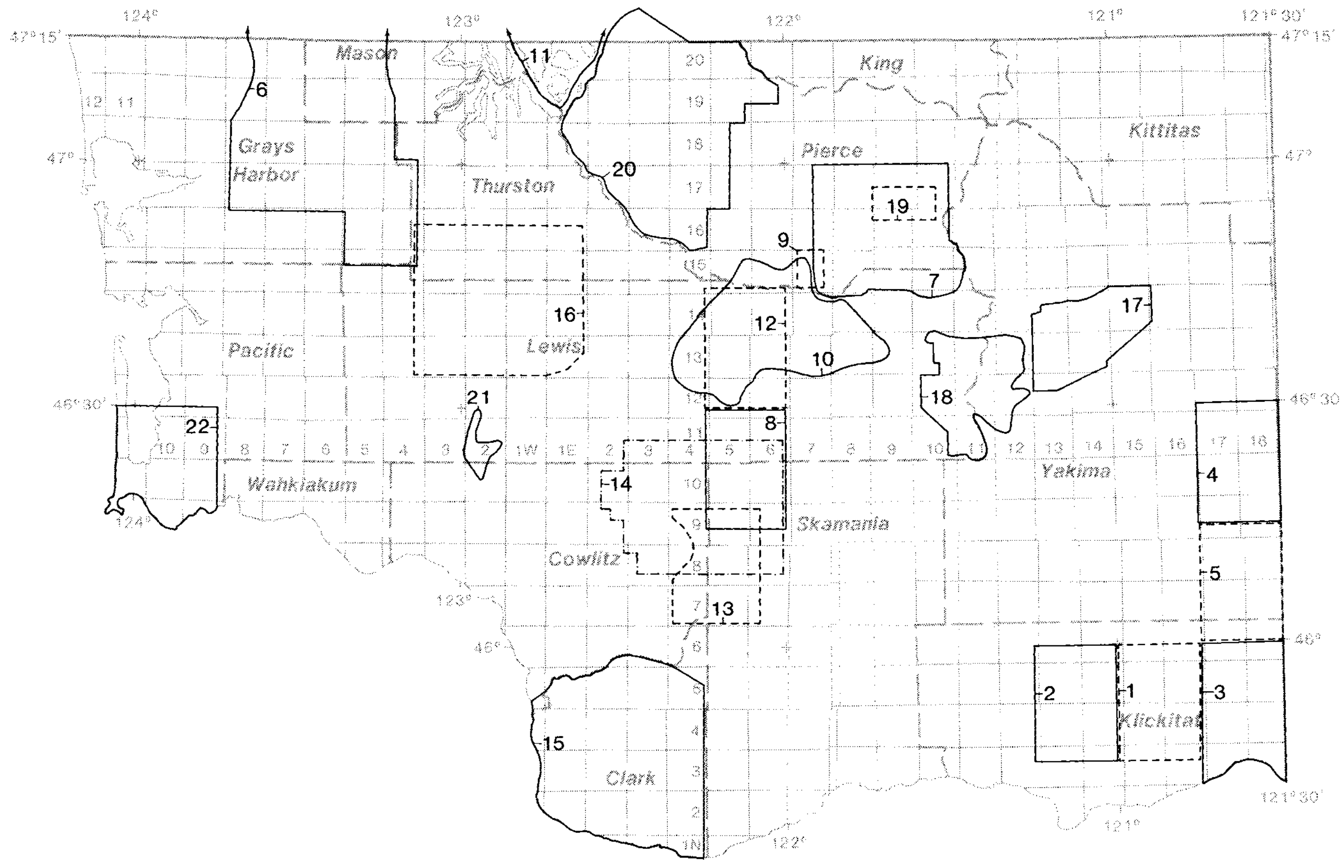

Figure 3.-Index to sources of map data, scales 1:31,680 through 1:60,500.

1. Anderson, 1987a; scale 1:38,400
2. Anderson, 1987b; scale 1:38,400
3. Anderson, 1986; scale 1:38,400
4. Bentley and Campbell, 1986; scale 1:48,000
5. Bentley and others, 1986; scale 1:48,000
6. Carson, 1970; plate I, scale 1:48,000
7. Crandell, 1969; plate 1, scale 1:48,000
8. Evarts and Ashley, 1984; scale 1:48,000
9. Evarts and others, 1983; figure 2, scale 1:43,700
10. Fisher, 1957; plate 5, scale 1:31,680
11. Garling and others, 1965; plate 1, scale 1:60,000
12. Gower, 1958; scale 1:48,740
13. Hopson, 1980; 2 sheets, scale 1:32,250
14. Lipman and Mullineaux, 1981; plate, scale 1:50,000
15. Mundorff, 1964; plate 2, scale 1:48,000
16. Snavely and others, 1958; plate 1, scale 1:48,000
17. Swanson, 1978; scale 1:48,000
18. Swanson and Clayton, 1983; plate, 1:48,000
19. Thompson, 1983; figure 2b, scale 1:50,600
20. Walters and Kimmel, 1968; plate 1, scale 1:50,000
21. Weaver, 1937; plate 4, scale 1:39,000
22. Wells, 1979; scale 1:48,000

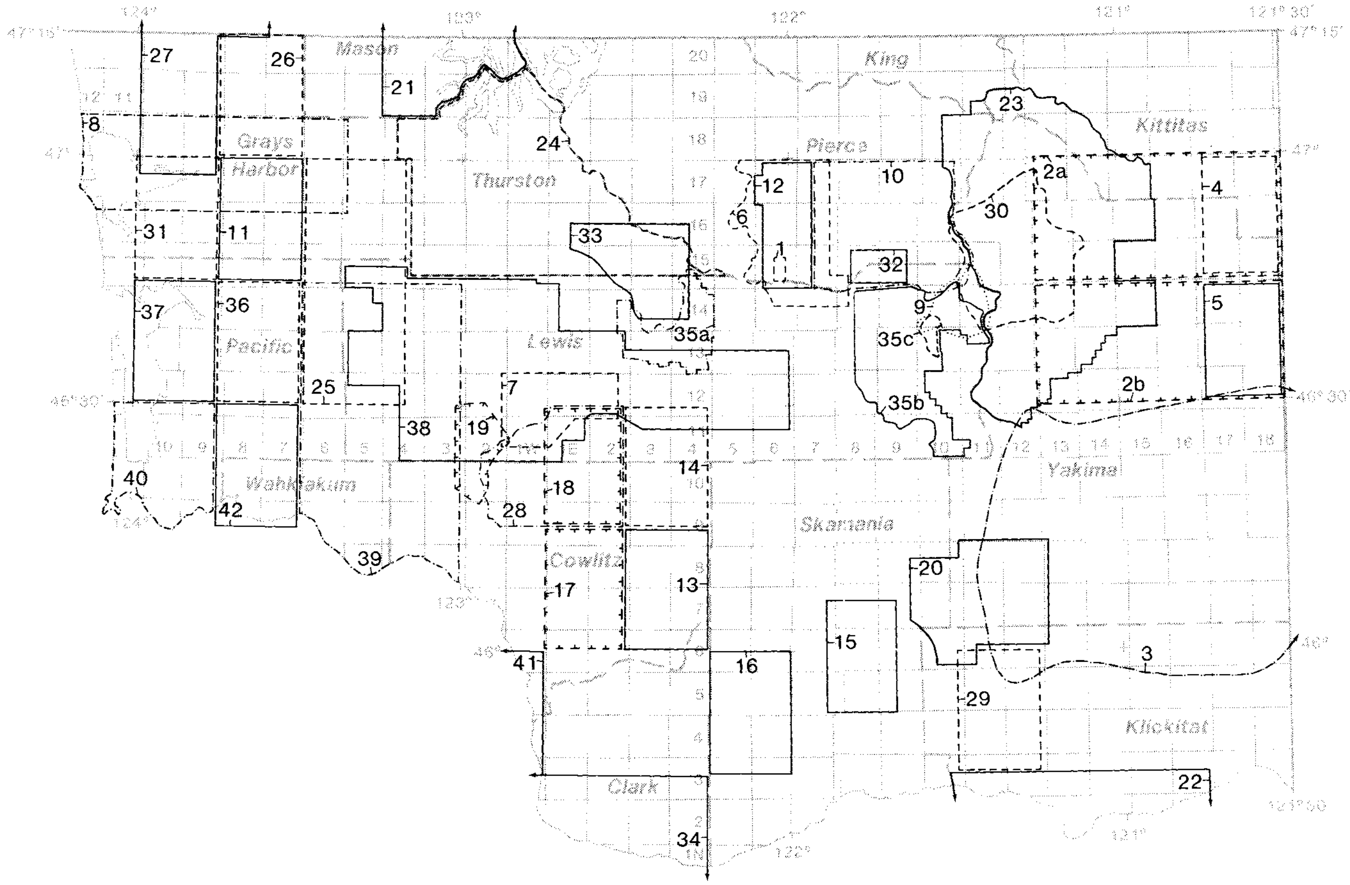

Figure 4-Index to sources of map data, scales 1:62,500 through 1:90,000.

1. Beeson, 1980; figure 2, scale 1:63,360
2a,b. Bentley, 1977; scale 1:70,000
3. Bentley and others, 1980; scale 1:84,480
4. Bentley and Campbell, 1983a; scale 1:62,500
5. Bentley and Campbell, 1983b; scale 1:62,500
6. Buckovic, 1974; plate 1, scale 1:63,360
7. Dethier and Bethel, 1981; plate, scale 1:62,500
8. Eddy, 1966; plate 1, scale 1:90,000
9. Ellingson, 1959; plate 24, scale 1:63,360
10. Fiske and others, 1963; plate 1, scale 1:62,500
11. Gower and Pease, 1965; scale 1:62,500
12. Hammond, 1960; 2 plates, scale 1:63,360
13. Hammond, 1985a; scale 1:62,500
14. Hammond, 1985b; scale 1:62,500
15. Hammond, 1985c; scale 1:62,500
16. Hammond, 1985d; scale 1:62,500
17. Hammond, 1985e; scale 1:62,500
18. Hammond, 1985f; scale 1:62,500
19. Henriksen, 1956; plate 1, scale 1:83,000
20. Hopkins, 1976; plate 1, scale 1:63,360
21. Molenaar and Noble, 1970; plate 1, scale 1:62,500
22. Newcomb, 1969; plate 1, scale 1:62,500
23. Niesen and Gusey, 1983; plate, scale 1:62,500
24. Noble and Wallace, 1966; plates 1 and 2, scale 1:72,400
25. Pease and Hoover, 1957; scale 1:62,500
26. Rau, 1967; figure 2, scale 1:62,500
27. Rau, 1986; scale 1:62,500
28. Roberts, 1958; plate 1, scale 1:62,500
29. Sheppard, 1964; scale 1:62,500
30. Simmons and others, 1983; plate 1, scale 1:62,500
31. Snavely, P. D., Jr., and Wagner, H. C., U.S. Geological Survey, 1985, written commun.; sketch map
32. Thompson, 1983; figure 2a, scale 1:75,000
33. Thorsen and Othberg, 1978; maps 2 and 3, scale 1:62,500
34. Trimble, 1963; plate 1, scale 1:62,500

35. U.S. Forest Service Gifford Pinchot National Forest, Packwood Ranger District, 1984, written commun.
    a, Mineral and Morton areas, 1 plate, scale 1:62,500
    b, Packwood area 1, 1 plate, scale 1:62,500
    c, Packwood area 2, 1 plate, scale 1:62,500
36. Wagner, 1967a; scale 1:62,500
37. Wagner, 1967b; scale 1:62,500
38. Weigle and Foxworthy, 1962; plates 2, 3, and 5, scale 1:63,360
39. Wells, 1981; scale 1:62,500
40. Wells, in press; scale 1:62,500
41. Wilkinson and others, 1946; 1 plate, scale 1:62,500
42. Wolfe and McKee, 1968; plate, scale 1:62,500

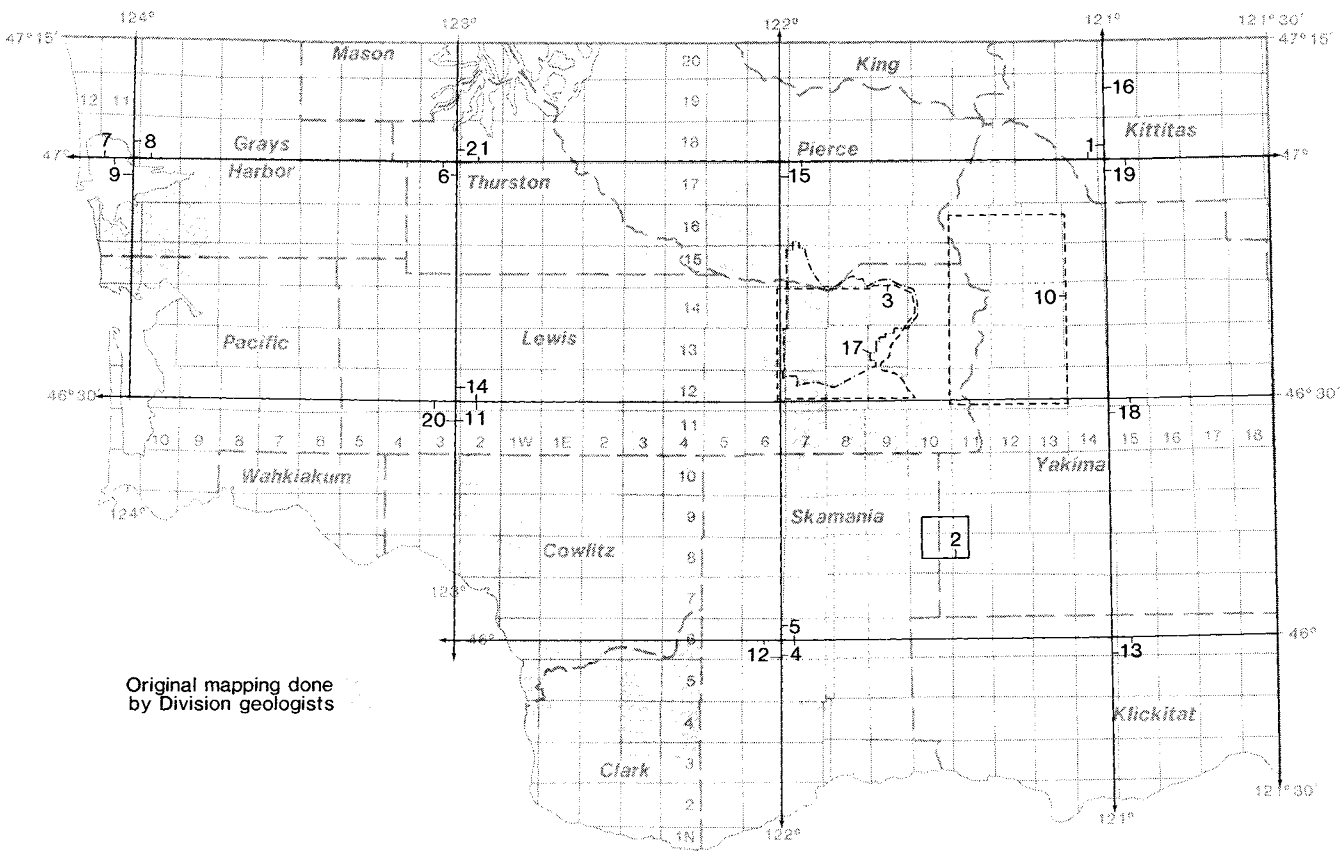

Figure 5-Index to sources of map data, scale 1:100,000.

1. Frizzell and others, 1984; plate
2. Hildreth and others, 1983; figure 2
3. M. A. Korosec, Div. of Geology and Earth Resources, 1985, written commun.; notes and unpublished map sheet
4. Korosec, 1987b
5. Korosec, 1987a
6. Logan, 1987a
7. Logan, 1987b
8. Logan, 1987b
9. Logan, 1987a
10. Miller, 1985; plate 1
11. Phillips, 1987a
12. Phillips, 1987b
13. Phillips and Walsh, 1987
14. Schasse, 1987a
15. Schasse, 1987b
16. Tabor and others, 1982; plate
17. U.S. Forest Service Gifford Pinchot National Forest, Packwood-Randle area, 1984; written commun.
18. Walsh, 1986a
19. Walsh, 1986b
20. Walsh, 1987a
21. Walsh, 1987b

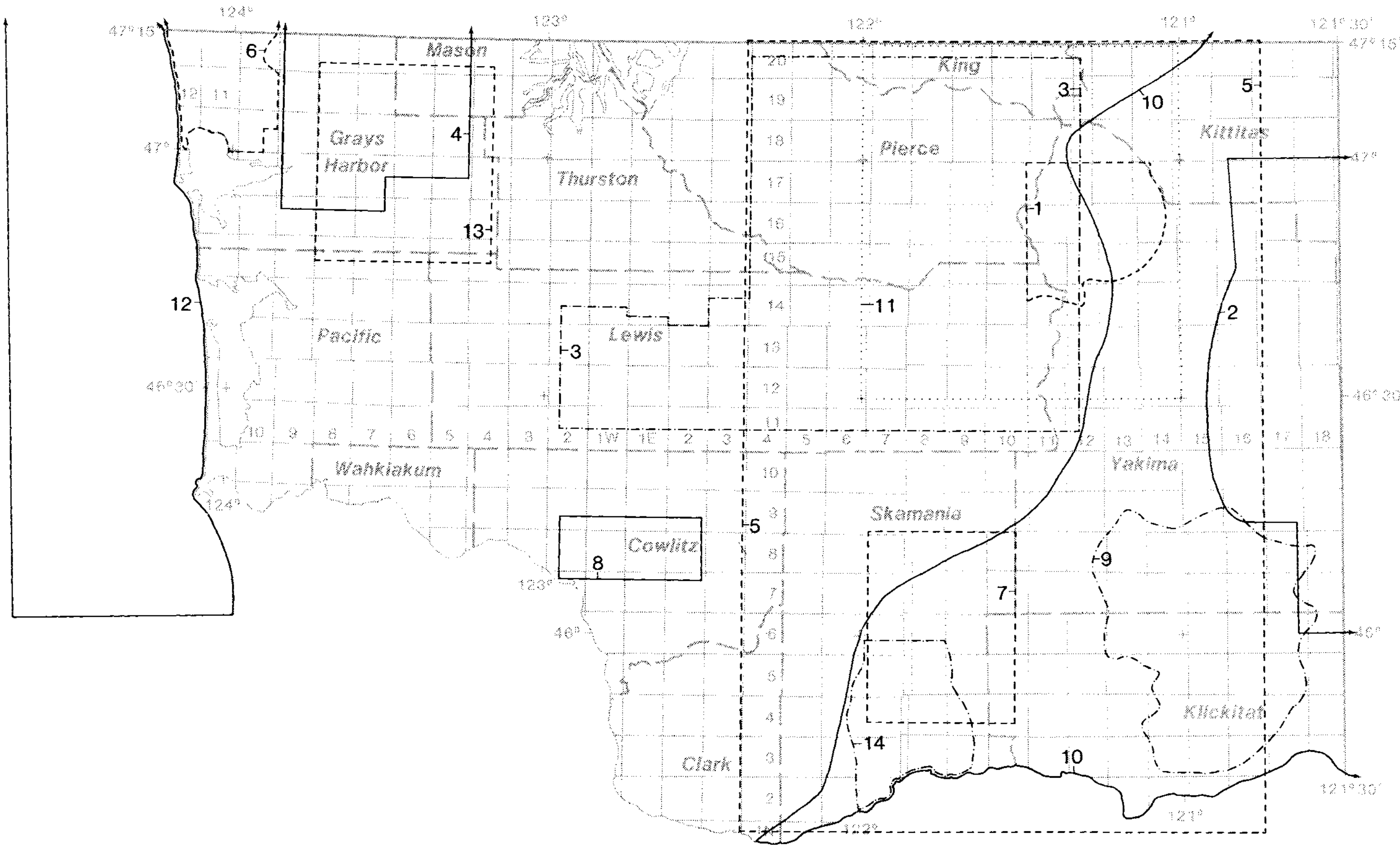

Figure 6–Index to sources of map data, scales 1:125,000 through 1:540,000.

1. Abbott, 1953; figure 4, scale 1:125,000
2. Campbell, 1979; scale 1:250,000
3. Crandell and Miller, 1974; plate 1, scale 1:250,000
4. Fowler, 1965; figure 6, scale 1:220,000
5. Hammond, 1980; 2 sheets, scale 1:125,000
6. Moore, 1965; plate 1, scale 1:125,000
7. Schuster and others, 1978; figure 2, scale 1:200,000
8. Scott, 1986; figure 1, scale >1:380,000
9. Sheppard, 1967; scale 1:125,000
10. Swanson and others, 1979a; 12 plates, scale 1:250,000
11. Vance and others, in press; figure 2, scale 1:540,000
12. Wagner and others, 1986; scale 1:250,000
13. Washington Public Power Supply System, 1982; figure 2.5-53, scale 1:250,000
14. Wise, 1970; plate 1, scale 1:125,000

ΦEm — Consists of the Lincoln Creek Formation and part of Unit B of Wolfe and McKee (1972). Age range is based on benthic foraminifera referable to the Refugian and Zemorrian Stages (Beikman and others, 1967; Wolfe and McKee, 1972). Contact relations are from Armentrout and others (1983).

Em_2 — Consists of part of the McIntosh Formation, Stillwater Creek Member of the Cowlitz Formation, siltstone of Skamokawa Creek, siltstone of Cliff Point, siltstone and sandstone at Omeara Point, siltstone at Shoalwater Bay, and part of Unit B of Wolfe and McKee (1972). Age range is based on benthic foraminifera referable to the Narizian Stage (Wells, 1981; Wells, in press; Wolfe and McKee, 1972). Contact relations of McIntosh Formation are modified from Armentrout and others (1983) to show unconformity between Narizian McIntosh and Ulatisian sediments within and conformably on the Crescent Formation (Em_1). Contact relations of other Em_2 units are from Wells (1981) and Wells (in press).

En — Consists of the Cowlitz Formation. Age range is based on foraminifera referable to the upper Narizian Stage (Armentrout and others, 1983). Contact relations of Cowlitz Formation are from Armentrout and others (1983). As used here, the Cowlitz Formation is the Olequa Creek Member of the Cowlitz Formation of Henriksen (1956) and the Cowlitz Formation as restricted by Wells (1981).

Evb — Consists of the volcanic rocks of Grays River (Walsh 1987a; Phillips, 1987a). Unit has yielded K-Ar ages ranging from about 37 m.y. (Phillips and others, 1986) at top of unit in stratigraphic column 4 to about 39 m.y. in this column (Wells and Coe, 1985). Interbedded sedimentary rocks contain Narizian benthic foraminifera (Wolfe and McKee, 1972; Wells, 1981); therefore unit base could be as old as about 48.5 m.y. Contact relations are from Wells (1981).

Evt — Includes the Pe Ell Volcanics Member of the Cowlitz Formation. Upper age limit is based on interfingering of these volcanic rocks with strata yielding Narizian benthic foraminifera (Henriksen, 1956). Lower age range is from unnamed tuffs near Point Ellice on the Columbia River that are interbedded with unit Em_1 (Wells, in press).

Em_1 — Includes the sandstone of Megler and Unit A of Wolfe and McKee (1972). Age range based on benthic foraminifera referable to the Ulatisian Stage (data from Wells, in press, and Wolfe and McKee, 1972, interpreted by W. W. Rau, oral commun., 1986). Contact relations are from Wells (in press) and Wolfe and McKee (1972).

Ev_c — Consists of the Crescent Formation. Age range of the Crescent Formation is from K-Ar dates of Duncan (1982). Contact relations are modified from Armentrout and others (1983) to emphasize unconformity between Evc and younger units.

Mvi_s — Consists of invasive Pomona Member of the Saddle Mountains Basalt (Wells and Niem, 1987). Same age as Mv_s above.

Mvi_g — Consists of invasive flows of R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt (Wells and Niem, 1987). Age range is same as for unit Mv_g.

Eiqm — Consists of the Ordway Creek stock (?). Age range is from zircon fission-track date of about 41 m.y.b.p. (R. E. Wells, U.S. Geological Survey, oral commun., 1986; fission-track date by J. A. Vance).

Eib — Age range uncertain. Basalt and gabbro sills do not cut unit ΦEm and tend to be localized near top of unit Ev_c (Wells, 1981). Unit is interpreted to be possible feeders of units Ev_c and/or Evb.

Column 2—Shelton, south half the Copalis Beach, Chehalis River, and Westport 1:100,000-scale Quadrangles

See Logan (1987a,b) for further stratigraphic details.

Qa — Assumed to be entirely of Holocene age.

Qb — Assumed to be entirely of Holocene age. Wiedeman (1984, p. 8-9) suggests most dune deposits along Washington coast are of Holocene age.

Qgo — Consists of Vashon outwash, undivided. Age of maximum ice advance in column area is variously estimated at 14,000 yr (Porter, 1970) to 12,600 yr (Carson, 1970). Estimated duration of the Vashon stade is from 13,500 to 15,000 yr ago (Porter, 1976).

Qgog — Consists of Vashon outwash gravel. Same age range as for Qgo.

Qgos — Consists of Vashon outwash sand. Same age range as for Qgo.

Qgt — Consists of Vashon till. Same age range as for Qgo.

Qgd — Consists of Vashon drift, undivided. Same age range as for Qgo.

Qga — Consists of the Colvos Sand and Vashon advance outwash. Shown diagrammatically as slightly older than other Vashon units. Precise age range is uncertain.

Qao — Consists of Chow Chow alpine glacial outwash deposits. Moore (1965) reports radiocarbon age of about 35,000 yr. Golder Associates (1986) place unit between 10,000 and 20,000 yr b.p. Pollen stratigraphy supports the possibility of two alpine glacial events during Chow Chow time: at about 45,000 yr b.p. and at 20,000 to 10,000 yr b.p. (Heuser, 1964).

Qoa — Two sedimentary units are represented. The younger consists of pre-Vashon-age interglacial Skokomish Gravel. Data for age range of the Skokomish Gravel are given in column 3 under unit Qoa. The older unit Qoa consists of undeformed gravels of Moore (1965). Age of the older unit is uncertain; it may correlate in part with the Wedekind Creek formation of Carson (1970), which has reversed magnetic polarity and is thus older than about 690,000 yr.

Qgp — Two sedimentary units of uncertain age are represented. The younger consists of the "Salmon Springs" deposits of Carson (1970), correlated by Easterbrook (1985) with the Double Bluff Drift. The Double Bluff age of about 140,000 yr is from Armentrout and others (1983). The older unit consists of the Helm Creek deposits of Carson (1970), which are normally magnetized (Woodward-Clyde Consultants, 1978) and hence less than 690,000 yr old. Woodward-Clyde Consultants (1978) suggest an age of about 250,000 to 690,000 yr for the Helm Creek unit.

Qapo — Two sedimentary units of uncertain age are represented. The younger deposits consist of the Humptulips and Mobray drifts, considered by Golder Associates (1986) to range between 140,000 and 150,000 yr b.p. and to correlate with the Double Bluff Drift (Easterbrook, 1985). The older deposits include the Wedekind Creek and Logan Hill Formations, both more than 690,000 yr old and possibly as old as 2 m.y. (Easterbrook, 1985).

Qap — Consists of the Weatherwax formation. Coeval with the Mobray drift and "Salmon Springs" of Carson (1970). (See unit Qapo above.)

Qc — Consists of the Damon silt of Moore (1965). Unit's age is uncertain, but unit may be interbedded with or slightly older than undeformed gravels of Moore (1965, p. 21).

QPLc — Age uncertain, but deformation and deep weathering suggest an age ranging into the Pliocene (Moore, 1965).

Mm_2 — Consists of the Montesano Formation. Age range is based on benthic foraminifera referable to the Mohnian and Delmontian Stages (Rau, 1967). Contact relations are from Armentrout and others (1983).

Mc — Consists of the Wilkes Formation. Upper age limit uncertain, but fossil leaves from the unit (discussed in column 4) are restricted to the Homerian megafloral stage (J. A. Wolfe, U.S. Geological Survey, oral commun., 1985). Contact relations are from Armentrout and others (1983).

Mv_s — Consists of the Pomona Member of the Saddle Mountains Basalt. Unit has yielded K-Ar ages of about 12 m.y. (McKee and others, 1977) in the Columbia Basin. Contact relations are from Armentrout and others (1983).

Mv_g — Consists of the R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt (Wells and Simpson, 1987). Age of Grande Ronde flows is bracketed between 17.0 and 15.5 m.y. (Reidel and others, 1987) by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area. Contact relations are from Armentrout and others (1983).

Mm_1 — Consists of the Astoria Formation. Age range is based on benthic foraminifera referable to the Saucesian, Relizian, and Luisian (?) Stages (Rau, 1967). Contact relations are from Armentrout and others (1983).

ΦEm — Consists of the Lincoln Creek Formation. Age range is based on benthic foraminifera referable to the Refugian and Zemorrian Stages (Beikman and others, 1967) and Galvinian, Matlockian, and Juanian molluscan stages (Armentrout, 1973). Contact relations are from Armentrout and others (1983).

En — Consists of the Skookumchuck and Cowlitz Formations. Age range is based on benthic foraminifera referable to the late Narizian Stage (Rau, 1981). Contact relations are from Armentrout and others (1983).

Em_2 — Consists of the Humptulips and McIntosh Formations. Age range is based on benthic foraminifera referable to the Narizian Stage (Rau, 1984, 1986). Contact relations are from Armentrout and others (1983) and Rau (1984, 1986).

Evt — Consists of the Pe Ell Volcanics Member of the Cowlitz Formation and the volcanic unit of the McIntosh Formation. Unit is interbedded with sedimentary rocks containing benthic foraminifera referable to lower Narizian stage (Henriksen, 1956; Wagner, 1967a). Contact relations are from Henriksen (1956) and Wagner (1967a).

Em_1 — Includes the Hoh Assemblage and parts of the Crescent and McIntosh Formations. Unit contains benthic foraminifera referable to the Ulatisian Stage (Rau, 1986, 1966; Wagner, 1967a).

Ev_c — Consists of the basalts of the Crescent Formation. Age range is from K-Ar and ^{40}Ar-^{39}Ar ages of Duncan (1982). Contact relations are modified from Armentrout and others (1983).

Mvi_s — Consists of the basalt of Packsack Lookout and invasive flow or flows of the Pomona Member of the Saddle Mountains Basalt. K-Ar age of 9.0 ± 1.4 m.y. reported by Snavely and others (1973, p. 414) appears too young. Unit is shown as same age as Mv_s above.

Eib — Age range uncertain. Basalt and gabbro sills do not cut unit ΦEm and tend to be localized near top of unit Ev_c. Unit is interpreted to be possible feeders of units Ev_c and/or Evb.

Column 3—Tacoma (south half) and Centralia 1:100,000-scale Quadrangles

See Walsh (1987b) and Schasse (1987a) for further stratigraphic details.

Qa — Assumed to be entirely of Holocene age.

Qp — Lower age range from Pleistocene radiocarbon dates reported by Tsukada and others (1981) from lakes containing peat. In addition, many peats overlie 13,500- 15,000-yr-old Vashon Drift. (See unit Qgo.) Deposition of peat and associated lithologies is assumed to continue throughout the Holocene.

Qvl — Consists of the Electron Mudflow, Osceola Mudflow, and Lily Creek Formation. See column 6 for details of mudflow age ranges. Lily Creek Formation is correlative with Alderton and Puyallup Formations (Crandell, 1963), hence older than about 0.66 or 0.89 m.y.b.p. [that is, fission-track age of type section, overlying Salmon Springs (Easterbrook and others, 1981)]. Mattinson (1977) reports zircon U-Pb age of about 2.9 m.y. from unit, but questions the date, and Hopson (*in* Crandell, 1963, p. A21) suggests the unit has a Pliocene age. Age of base of Lily Creek uncertain and placed arbitrarily at base of the Pleistocene.

Qgo — Consists of Vashon outwash, undivided. For the column area, Crandell (1963, p. A9) estimates the age range at 15,000 to 25,000 yr for Vashon stade; however, a range 13,500 to 15,000 yr (Porter, 1976) is adopted for use in all stratigraphic columns where Vashon Drift is shown.

Qgog — Consists of Vashon outwash gravel. Same age range as for Qgo.

Qgos — Consists of Vashon outwash sand. Same age range as for Qgo.

Qgt — Consists of Vashon till. Same age range as for Qgo.

Qgd — Consists of Vashon drift, undivided. Same age range as for Qgo.

Qga — Consists of the Colvos Sand and Vashon advance outwash. Unit is shown diagrammatically as slightly older than other Vashon units. Precise age range is uncertain.

Qao — Consists of the Evans Creek outwash. Age range from Dethier and Bethel (1981, p. 5) and Armstrong and others (1965).

Qad — Consists of the Evans Creek Drift. Age range from Dethier and Bethel (1981, p. 5) and Armstrong and others (1965).

Qoa — Consists of the Skokomish Gravel. Molenaar and Noble (1970, p. 16-17) report that lower part of unit is interbedded with the Kitsap Formation. (See unit Qc, this column.) Upper age limit of unit is uncertain, but the unit is overlain by Vashon Drift.

Qc — Consists of the Kitsap, Alderton, and Puyallup Formations. Radiocarbon dates from the Kitsap Formation indicate a probable age range of older than about 50,000 yr to as as young as 27,900 yr (Walsh, 1987b). Puyallup and Alderton Formations lie stratigraphically beneath 0.66- or 0.87-m.y.-old type Salmon Springs Drift (Easterbrook and others, 1981). Age of base of Alderton is unknown but probably Pleistocene (Crandell, 1963).

Qgp — Includes the Salmon Springs, Orting, and Stuck Drifts. Younger deposits correspond to Salmon Springs (?) and "pre-Salmon Springs" drifts of Noble and Wallace (1966). Salmon Springs (?) is correlated with Double Bluff or Possession Drift by Easterbrook (1985). Older deposits consist of type Salmon Springs, Stuck, and Orting Drifts. The type Salmon Springs Drift yielded zircon fission-track ages of 0.66 and 0.87 m.y. (Easterbrook and others, 1981). Stuck Drift lies beneath the type Salmon Springs and above the Orting Drifts. The reversely magnetized Orting Drift is thought by Easterbrook (1985) to be as old as 2 m.y.

Qapo — Consists of outwash deposits of The Hayden Creek and Wingate Hill Drifts and of Logan Hill Formation. Hayden Creek unit has an age range of 70,000 to 140,000 yr b.p. (Dethier and Bethel, 1981, p. 6) with a "preferred" age of about 140,000 yr (Colman and Pierce, 1981). The Wingate Hill is older than 140,000 yr and possibly as old as 500,000 yr (Dethier and Bethel, 1981; Colman and Pierce, 1981). Age range of The Logan Hill unit is uncertain, but its high degree of weathering suggests an early Pleistocene to late Pliocene age (Easterbrook, 1985).

Qap — Consists of the Hayden Creek and Wingate Hill Drifts. Age range as described in unit Qapo above.

Qva — Consists of Mount Rainier andesite. Pre-dates Hayden Creek Drift (Qap) and dated by K-Ar at 300,000 and 660,000 yr (Crandell and Miller, 1974).

Mc — Consists of the Wilkes and Mashel Formations. Age range is from fossil flora assigned to the Homerian megafloral stage by J. A. Wolfe (U.S. Geological Survey, oral commun., 1985; also *in* Walters and Kimmel, 1968). Contact relations are from Armentrout and others (1983).

Mvc — Two units are represented. The younger unit corresponds to Miocene volcanic sediments of Gard (1968); age range of this unit assumed to be the same as for Mc above. Older unit's age range based on K-Ar age determination of 23.2 ± 1.7 m.y. from interbedded andesite flow (Mva). Contact relations are from Gard (1968) and Schasse (1987a).

Mv_g — Consists of the N_2 magnetostratigraphic unit of the Grande Ronde Basalt. Ages of Grande Ronde flows are bracketed between 17.0 and 15.5 m.y.b.p. (Reidel and others, 1987) by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area. Just west of the area, unit is dated by K-Ar (plagioclase) at 15.3 ± 0.8 m.y.b.p. (Turner, 1970). Contact relations are from Armentrout and others (1983).

Mva — Age range based on K-Ar age dates of 20.7 ± 0.3 and 23.2 ±1.7 m.y.b.p. (Phillips and others, 1986). The K-Ar ages may be too young; see discussion in Schasse (1987a, p. 10) and Hagen (1987). Contact relations are from Schasse (1987a).

Mvb — Age range and contact relations from correlation with units dated by Evarts and others (in press) and Phillips and others (1986). See units Mvb and Mva in column 4.

MΦvt — Age range and contact relations uncertain. Tentatively correlated with the Stevens Ridge Formation of column 6.

ΦEm — Consists of the Lincoln Creek Formation. Age range is based on benthic foraminifera referable to the Refugian and Zemorrian Stages (Rau, 1981). Contact relations are from Armentrout and others (1983).

Φva — Includes probable time-rock correlatives of the Ohanapecosh Formation (Φvc) (Fiske and others, 1963). Age range is from K-Ar date of 27.0 ± 1.8 m.y.b.p. (Phillips and others, 1986) and from correlation with Ohanapecosh Formation type section in column 6 (Vance and others, in press). Contact relations are uncertain.

Φvc — Consists of the Ohanapecosh Formation. Age control is from zircon fission-track ages of about 36.5 to about 28 m.y. in correlative strata of column 6 (Vance and others, in press). Contact relations are uncertain.

ΦEva — Includes part of the Hatchet Mountain Formation and the Northcraft Formation as extended by Hammond (1980), Roberts (1958), and Buckovic (1974). Age range is based on regional correlation with Goble Volcanics (discussed in unit ΦEva in column 4) and a whole-rock K-Ar age of about 35.8 m.y. (Phillips and others, 1986). Contact relations are from Schasse (1987a, p. 12-13).

ΦEvc — Includes part of the Hatchet Mountain Formation and the Northcraft Formation as extended by Hammond (1980), Roberts (1958), and Buckovic (1974). Age range is based on units that are interbedded with dated unit ΦEva.

ΦEvt — Age range based on probable interbedded relationship with units ΦEva and ΦEvc.

Eva — Consists of the Northcraft Formation. In the type area, the Northcraft Formation lies beneath upper Narizian Skookumchuck Formation (unit En) and above lower Narizian McIntosh Formation (unit Em_2; Snavely and others, 1958). Whole-rock K-Ar ages from the unit are about 38 and 39 m.y. (Phillips and others, 1986). Contact relations are modified from Armentrout and others (1983), Schasse (1987a, p. 15), and Hagen (1987).

Evc — Age range based on correlation with parts of the Northcraft Formation and the Puget Group (Schasse, 1987a, p. 16). Contact relations from Schasse (1987a, p. 16).

En — Consists of the Skookumchuck Formation. Age range is based on foraminifera referable to the late Narizian Stage (Rau, 1981) and K-Ar age dates that average about 40 m.y.b.p. (Triplehorn and others, 1980). Contact relations are modified from Armentrout and others (1983) to show interbedding with the Northcraft Formation (unit Eva).

Em_2 Consists of the McIntosh Formation. Age range is based on foraminifera referable to the Narizian Stage (Rau, 1981). Contact relations are modified from Armentrout and others (1983) to show probable unconformity at base of unit.

Ec_2 Consists of the Puget Group, Spiketon, and Carbonado Formation. Age range is based on correlation with type Puget Group outside map area. Age range of the type Puget Group is based on a megafloral assemblage that spans the middle to late Eocene (Wolfe, 1968). Age of unit's base is uncertain but interpreted to coincide with base of unit Em_2. Contact relations are after Gard (1968), Buckovic (1974), and Hammond (1980).

Ev_c Consists of the Crescent Formation. Age range is from K-Ar and ^{40}Ar-^{39}Ar ages of Duncan (1982). Contact relations are modified from Armentrout and others (1983) to show unconformity between Ev_c and Em_2.

Mir Age range uncertain; intrudes 27-m.y.-old andesite flows. (See unit Φva.)

MΦib Age range uncertain; based on compositional similarity between intrusions and Miocene and Oligocene volcanic rocks (Schasse, 1987a, p. 18). Unit intrudes Eocene strata (units Em_2, En, Eva), hence is post-Eocene (Snavely and others, 1958).

MΦid Age range uncertain; based on compositional similarity between intrusions and Miocene volcanic rocks (Schasse, 1987a, p. 18). Unit intrudes Eocene strata (units Ec_2 and Eva), hence is probably post-Eocene (Gard, 1968).

MΦian Age range uncertain; based on compositional similarity between intrusions and Miocene volcanic rocks (Schasse, 1987a, p. 18). Unit intrudes strata of Eocene through lower Oligocene age, hence is post-lower Oligocene.

Column 4—Mount St. Helens 1:100,000-scale Quadrangle

See Phillips (1987a) for further stratigraphic details.

Qa Assumed to be Holocene.

Qt Age range and correlation uncertain but probably consists of flood deposits of glacial Lake Missoula. Age range of 12,700 to 15,300 yr b.p. (Waitt, 1985, p. 1284). Contact relations are from Livingston (1966).

Qad Consists of part of the Evans Creek Drift. Age range of 13,000 to 22,000 yr b.p. from Dethier and Bethel (1981, p. 5).

Qao Consists of outwash of Evans Creek Drift. Age range same as for unit Qad.

Qap Consists of part of the Hayden Creek Drift and Wingate Hill Drift (?). Age range is uncertain; age range shown is from preferred option of about 140,000 yr b.p. of Colman and Pierce (1981) for Hayden Creek and "several hundred thousand years and possibly older" (Dethier and Bethel, 1981, p. 6) for the Wingate Hill.

Qapo Consists of alpine glacial outwash of the Hayden Creek and Wingate Hill Drifts, and Logan Hill Formation. Age range of all units is uncertain. Age of Hayden Creek as for unit Qap.) Wingate Hill is older than 140,000 yr and may be as old as 500,000 yr in its type area (Easterbrook, 1985). According to Dethier and Bethel (1981, p. 6-7), the Logan Hill is older than 630,000 yr and may be as much as 1 to 1.5 m.y. old. Easterbrook (1985) speculates that the Logan Hill Formation is as old as 2 m.y.

Qvp Consists of the A.D. 1980 pyroclastic flow deposits of Mount St. Helens. (See Mullineaux and Crandell, 1981.)

Qvl Age range spans A.D. 1980 through earliest products of ancestral Mount St. Helen's volcano, 35,000-40,000 yr b.p. (Mullineaux, 1986).

Qvc Age range spans prehistoric eruptive activity of Mount St. Helens, from about 100 to 35,000-40,000 yr b.p. (Mullineaux and Crandell, 1981).

Qvb Two units are labeled Qvb on the column. The younger includes the Cave Basalt, whose radiocarbon age is about 1,900 yr (Greeley and Hyde, 1972) and from tephrochronology for rocks of the Kalama eruptive period (Mullineaux, 1986). Older unit has age range defined by probable glaciated surface (Phillips, 1987a, p. 24-25), normal magnetic polarity, and stratigraphic position of the unit beneath Mount St. Helens tephra set C (older than 37,600 yr; Mullineaux, 1986); associated with portion of unit Qva dated at 0.16 m.y.b.p. (Hammond, 1980, p. 19; Hopson, 1980; Hammond and Korosec, 1983).

Qva Two units are represented. Younger unit consists of flows of the Kalama eruptive period on the cone of Mount St. Helens and a glaciated (?) flow flanking the cone (Hopson, 1980). Older unit dated at 0.16 m.y.b.p. by whole-rock K-Ar (Hammond and Korosec, 1983).

QPc Consists of the Troutdale Formation. Precise age control in column area is lacking, but unit's age could be limited to Pliocene (Livingston, 1966). Age range shown is based on data for this unit as described in column 5. Contact relations are from Livingston (1966) and Phillips (1987a).

Mc Consists of the Wilkes Formation. Age range based on fossil leaves (Roberts, 1958) referable to the Homerian Stage (J. A. Wolfe, U.S. Geological Survey, oral commun., 1986). Contact relations are from Roberts (1958).

Mv_g Consists of the R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt of the Columbia River Basalt Group (Phillips, 1987a, p. 28-29). Age range of the Grande Ronde Basalt is bracketed by K-Ar and ^{40}Ar-^{39}Ar age determinations made outside the column area of between 17.0 and 15.5 m.y.b.p. (Reidel and others, 1987).

Mvb, Mva, Mvd, Mvc, and Mvt Units are complexly interbedded and form heterogeneous volcanic section (Phillips, 1987a, p. 29-31; Evarts and Ashley, 1984). Age range based on plagioclase K-Ar ages of 25 to about 23 m.y. (Evarts and others, in press). Contact relations are from Evarts and Ashley (1984) and Evarts and others (in press).

MΦvt Age range and contact relations uncertain. Tentatively correlated with the Stevens Ridge Formation of column 6 (Hopson, 1980; Hammond, 1980).

Φvb Age range based on K-Ar age of 28.5 m.y. (Evarts and others, in press). Contact relations from Evarts and Ashley (1984).

Φva Age range based on K-Ar ages of about 28 to 29 m.y. (Evarts and others, in press). Contact relations from Evarts and Ashley (1984).

Φvd Age range uncertain. Most of the unit consists of dacite interbedded with unit Φvc. Some of unit consists of hydrothermally altered rocks (Phillips, 1987a) possibly associated with 20-24-m.y.-old Spirit Lake pluton. (See units Miq, Migd, and Miqm.) Contact relations are from Phillips (1987a).

Φvt Age range uncertain and based on interbedding of unit with dated units Φvb and Φva. Contact relations from Evarts and Ashley (1984) and Phillips (1987a).

Φvc Age range uncertain. At base of unit, age is suggested by presence of Goshen-type floral assemblage (Wolfe, 1961) and its position stratigraphically above 38-35-m.y.-old Goble Volcanics (units ΦEva and ΦEvc Phillips, 1987a). A ^{40}Ar-^{39}Ar age of about 36 m.y. (R. C. Evarts, U.S. Geological Survey, oral commun., 1986) suggests the base may be older than shown. Contact relations between Φvc and underlying ΦEva or ΦEvc are unclear in parts of column area and may be unconformable (Phillips, 1987a; Schasse, 1987a). Age range of top of unit based on interbedding of unit with lava flows (units Φva and Φvb) yielding plagioclase K-Ar ages of about 28 to 29 m.y.; a tuff in the unit has a plagioclase K-Ar age of about 27 m.y. (Evarts and others, in press). Contact relations are from Evarts and Ashley (1984), Evarts and others (in press), and Phillips (1987a).

ΦEva Consists of part of the Goble Volcanics. Age range is uncertain; K-Ar dates range from about 45 to 32 m.y.b.p. (Beck and Burr, 1979; Armentrout and others, 1983; Phillips, 1987a). This range conflicts with regional biostratigraphic data: ΦEva is interbedded at its base with unit En (Cowlitz Formation), which contains upper Eocene foraminifera and molluscs (Wilkinson and others, 1946; Livingston, 1966), and near its top with unit ΦEn (Toutle Formation), which contains uppermost Eocene and lower Oligocene foraminifera, molluscs, and megaflora (May, 1980; Roberts, 1958; Wolfe, 1968, 1981). Lava flows overlying the Goble have K-Ar ages of about 36 to 33 m.y. (Phillips and others, 1986). Probable stratigraphic age range is about 38 to 35 m.y. Contact relations are from Phillips (1987a).

ΦEvc Consists of part of the Goble Volcanics. Age range from correlation and interbedding relations with unit ΦEva. Contact relations from Phillips (1987a).

ΦEn Consists of the Toutle Formation. Age range based in part on Kummerian megafloral assemblages (Wolfe, 1968, p. 6-7; Wolfe, 1981, p. 42-43), Galvinian molluscs (Roberts, 1958; May, 1980), and Refugian benthic foraminifera (Roberts, 1958). Lava flow capping Toutle Formation yielded a plagioclase K-Ar age of 33.9 $\pm$ 1.7 m.y. (Phillips and others, 1986; Phillips, 1987a). Contact relations are from Phillips (1987a).

En Consists of the Cowlitz Formation and Olequa Creek Member of the Cowlitz Formation. Unit contains upper Narizian benthic foraminifera (Henriksen, 1956) and Cowlitz-Coaledo molluscs (Armentrout, 1981). An interbedded basalt flow (unit Evb) yielded a whole-rock K-Ar age of about 37 m.y.(Phillips and others, 1986). Contact relations are from Phillips (1987a).

Evb Consists of the volcanic rocks of Grays River. Age range is based on interbedding of lava flows and volcanic-derived sedimentary rocks with unit En. A basalt flow near the stratigraphic top of the unit yielded a whole-rock K-Ar age of 37.3 $\pm$ 2.2 m.y.(Phillips and others, 1986).

Qida Age range from present to about 35,000-40,000 yr b.p. (Mullineaux and Crandell, 1981; Mullineaux, 1986).

QRida Consists of plug (dacite porphyry) of Goat Mountain. Age range based on biotite K-Ar dates of about 0.7 to 1.0 m.y. b.p. and about 3.0 m.y.b.p. from hornblende K-Ar (Hammond, 1980).

Mia Consists of copper-porphyry-type alteration at the Spirit Lake pluton. Age based upon secondary biotite K-Ar ages of about 17 m.y. (Evarts and others, in press; Armstrong, 1978).

Miq Consists of main phase of Spirit Lake pluton. Age range from numerous biotite K-Ar ages and zircon fission-track ages of about 21 to 22 m.y. (Evarts and others, in press). Position on stratigraphic column of associated phases Miqm and Migd indicates relative order of intrusion (Evarts and Ashley, 1984).

Miqm Consists of late granitic phase of Spirit Lake pluton. Age range as indicated for unit Miq.

Migd Consists of early granodiorite phase of Spirit Lake pluton. Age range as indicated for unit Miq.

Column 5—Vancouver 1:100,000-scale Quadrangle

See Phillips (1987b) for further stratigraphic details.

Qa Assumed to be Holocene.

Qoa Unit lies above flood deposits of glacial Lake Missoula (units Qfs, Qfg) and below unit Qa (Mundorff, 1964); upper age limit therefore uncertain.

Qp Lower age limit from radiocarbon dates of about 17,000-32,000 yr b.p. at Fargher Lake (Heuser and Heuser, 1980) and less than 13,080 yr b.p. at Orchard peatlands (Barnosky, 1983). Deposition of peat and associated lithologies is assumed to continue throughout Holocene.

Qfs Age range of 12,700 to 15,300 yr b.p. from Waitt (1980, p. 1284).

Qfg Same age range as for unit Qfs.

Qad Includes part of the Evans Creek Drift. Age range based on correlation of unit (Polivka, 1984; Hammond, 1980; Mundorff, 1984) with type Evans Creek Drift of column 3.

Qvc Age range of about 2,500 to 35,000-40,000 yr b.p. from numerous radiocarbon and dendrochronology age dates of Mount St. Helens volcanic units (Mullineaux, 1986; Mullineaux and Crandell, 1981).

Qvb Lower age range from K-Ar date of 360,000 $\pm$ 10,000 yr b.p. (Polivka, 1984). Upper age range based on radiocarbon date of 8,000 $\pm$ 300 yr b.p. and on geomorphology, which suggest limiting age of 2,000 yr (Polivka, 1984).

Qva Age range based on correlation with comagmatic basalt flows of unit Qvb (Polivka, 1984).

Qap Consists of part of the Hayden Creek Drift and Amboy drift. Age range based in part on infinite radiocarbon age (greater than 50,000 yr) (Mundorff, 1984) and stratigraphic position below deposits of Mount St. Helens (unit Qvc; Mundorff, 1984). Correlated with type Hayden Creek Drift of column 3 by Hammond (1980) and Mundorff (1984).

Qapo — Consists of parts of the Hayden Creek Drift and Amboy drift. Same age range as for unit Qap.

QPlvb — Consists of part of the Boring Lava. Age range is uncertain. Interbedded with strata (unit QPlc) containing megaflora referred to the Pliocene (Trimble, 1963). One flow is dated by whole-rock K-Ar at 1.53 ± 0.2 m.y.b.p. (Hammond and Korosec, 1983).

QPlva — Consists of part of the Boring Lava. Age range from correlation with comagmatic unit QPlvb.

QPlc — Consists of the Troutdale Formation. Precise age range is uncertain. Unit contains megaflora referred to the Pliocene (Trimble, 1963). Interbedded with basalt flow (unit QPlvb) dated at about 1.5 m.y.b.p. (Hammond and Korosec, 1983).

Mv_s — Consists of the Pomona Member of the Saddle Mountains Basalt. Unit has yielded K-Ar ages of about 12 m.y. (McKee and others, 1977) in the Columbia Basin. Contact relations are from Armentrout and others (1983).

Mv_w — Consists of the Priest Rapids and Frenchman Springs Members of the Wanapum Basalt. The Priest Rapids Member is about 14.5 m.y. old (Reidel, 1984, fig. 2). The Frenchman Springs Member has an average K-Ar age of about 15.3 m.y. (Beeson and others, 1985). Contact relations are from Tolan (1982) and Tolan and Beeson (1984).

Mv_g — Consists of R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt (Wells and Simpson, 1987). Age of Grande Ronde flows is bracketed between 17.0 and 15.5 m.y. (Reidel and others, 1987) by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area. Contact relations are from Armentrout and others (1983).

Mcg — Consists of the Eagle Creek Formation. Same age range as for unit Mcg in column 8 except that age of contact with overlying Mv_g is uncertain; contact may be conformable, implying that the upper age limit of unit is about 17 m.y. Contact relations are from Hammond (1980), Phillips (1987b), and Korosec (1987b).

Mva — Consists of the lava flows of Three Corner Rock. Age range based on K-Ar ages of about 17 m.y. for equivalent Stevenson Ridge lava flows (Berri and Korosec, 1983) and about 24 m.y. for unit Mvb (Phillips and others, 1986). Unit overlies strata of pre-Miocene age (Phillips, 1987b).

Mvb — Age range based on K-Ar age of 23.6 ± 1.2 m.y. (Phillips and others, 1986). Contact relations from Phillips (1987b).

MΦvt — Age and contact relations uncertain. Underlies unit Mvb and tentatively correlated (Hammond, 1980) with Stevens Ridge Formation (MΦvt, column 6) and unit Mvt in column 7.

Φvc — Age range uncertain. Cut by 19-m.y.-old Silver Star pluton (unit Migd). Correlative strata in column 4 yielded ^{40}Ar-^{39}Ar date of about 36 m.y.b.p. (R. C. Evarts, U.S. Geological Survey, oral commun., 1987) and contain a Goshen megaflora (Wolfe, 1961). Underlies unit Mvb, about 24 m.y. old (Phillips, 1987b).

Φva — Includes part of the Skamania volcanic rocks. Age range uncertain. Unit is cut by 19-m.y.-old Silver Star pluton (unit Migd). Upper part of unit yielded K-Ar ages of about 28 m.y. (Phillips and others, 1986); lower portion overlies unit ΦEva, hence is probably less than about 34-37 m.y. old (Phillips, 1987b).

Φvt — Age range uncertain. Stratigraphically lies between parts of units Φva and ΦEva, and probably correlative with parts of unit Φvc (Phillips, 1987b).

ΦEva — Consists of part of the Goble Volcanics. Age range uncertain because of wide range of K-Ar dates, from about 45 to 32 m.y.b.p. (Beck and Burr, 1979; Armentrout and others, 1983; Phillips, 1987a; see also column 4). This age range conflicts with abundant regional biostratigraphic data. A more probable stratigraphic age range (from K-Ar data and regional geologic constraints described in Phillips, 1987a,b) is about 38 to 35 m.y. Contact relations from Phillips (1987b).

ΦEvc — Consists of part of the Goble Volcanics. Age range from correlative and interbedded unit ΦEva.

Qida — Consists of Pleistocene dacite dome at Tumtum Mountain. Dacite has normal remanent magnetic polarity and overlies unit Qap (Mundorff and Eggers, in press), hence is younger than about 140,000 yr. Upper age limit is uncertain, but unit appears to be older than latest alpine glaciation (Mundorff and Eggers, in press).

Migd — Consists of part of the Silver Star pluton and associated smaller intrusive bodies. Age range from K-Ar age of 19.6 ± 0.7 m.y. (Power and others, 1981). The relative age of intrusion implied for units Migd, Miq, Mid, and Mian in the stratigraphic column is from cross-cutting relations established by Shepard (1980) and Schriener (1978).

Miq — Consists of part of the Silver Star pluton. Same age range as for unit Migd.

Mid — Consists of part of the Silver Star pluton and associated smaller intrusions. Same age range as for unit Migd.

Mian — Includes part of the Silver Star pluton. Near this pluton, the unit has same age range as unit Migd. Elsewhere, the age range is uncertain; unit may be associated with late Oligocene to Miocene volcanism.

Column 6—Mount Rainier 1:100,000-scale Quadrangle

See Schasse (1987b) for further stratigraphic details.

Qa — Assumed to be largely of Holocene age based on undissected character.

Qvl — Includes Electron and Osceola Mudflows, and Greenwater lahar. Radiocarbon ages for the Osceola Mudflow are 5,500-5,800 yr and for the Electron mudflow about 600 yr (Crandell, 1971, p. 24 and 56, respectively). Contact relations with the Osceola and tephra units indicate the Greenwater lahar is 5,700-6,600 yr old (Crandell, 1971, p. 21).

Qad — Includes Garda, Burroughs Mountain, McNeely, and Evans Creek Drifts. Age ranges are from Crandell and Miller (1974).

Qva — Includes andesites of Mount Rainier and Tieton Andesite. Andesite on summit of Mount Rainier is 2,200 yr old or less (Crandell, 1971, p. 11). Age of remainder of Mount Rainier andesite, from plagioclase and whole-rock K-Ar determinations, is from Crandell and Miller (1974, p. 17). Age range for andesites in the White Pass area from Clayton (1983), and for Tieton Andesite from Swanson (1978), Hammond (1980), and Clayton (1983).

Qvb Age for basalts at Tumac Mountain in the White Pass region is from Clayton (1983), and for other basalts in the column area from Swanson and Clayton (1983), Hammond (1980), and Swanson (1978).

Qvd Age range for dacite flows at Spiral Butte and along the Clear Fork of the Cowlitz River is from Clayton (1983) and Hammond (1980).

Qap Includes the Hayden Creek Drift. Age range from Crandell and Miller (1974), Porter (1976), Waitt (1977), and Clayton (1983).

QPlvd Age range from Hammond (1980) and Swanson and Clayton (1983).

QPlva Includes andesite of Bee Flat. Age range from Clayton (1983), Fiske and others (1963), and Swanson and Clayton (1983).

QPlvb Includes mafic rocks of Hogback Mountain. Age range from Clayton (1983).

Plc Age and contact relations from G. A. Clayton, Univ. of Washington (written commun., 1985).

Plvt Age uncertain. Position on diagram based on correlation with unit Plvr.

Plvd Age range from Clayton (1983) and Schreiber (1981).

Plvr Consists of Devils Horns rhyolite. Age range from zircon fission-track ages of about 3.2 m.y. (Clayton, 1983).

Plvb Includes Devils Washbasin basalt. Age range for this basalt is from K-Ar dates of about 3 m.y.b.p. (Clayton, 1983) and stratigraphic relations with unit Plvr. Additional age range shown indicates possible age of basalt flows on Bethel and Russell Ridges north of Rimrock Lake (Swanson, 1964, 1978).

Mc Consists of two units. Younger unit consists of the Ellensburg Formation, whose age is reported in Laursen and Hammond (1974); unit is interbedded with dated flows of the Columbia River Basalt Group to east of column area. Older unit near Packwood yielded a zircon fission-track age of 23.5 ± 0.6 m.y. (G. A. Clayton *in* Schasse, 1987b, p. 18 and 40). Contact relations for the older unit are from Schasse (1987b, p. 18).

Mv$_g$ Consists of the N_1, R_2 and N_2 magnetostratigraphic units of the Grande Ronde Basalt (Swanson and others, 1979b). Age of Grande Ronde flows is bracketed between 17.0 and 15.5 m.y. (Reidel and others, 1987) by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area.

Mvc Includes the Randle laharic breccia-conglomerate of Fisher (1960). Age range from intertonguing relation with dated units Mva and Mvb (Schasse, 1987b, p. 17, 19).

Mvt Includes welded tuff of the Palisades and part of the Stevens Ridge Formation. Age range for the Palisades tuff from Mattinson (1977). Age range and contact relations of the Stevens Ridge Formation from Frizzell and others (1984), and Hartman (1973).

Mva Includes the Fifes Peak Formation. Age from Hartman (1973), Vance and others (in press), and Phillips and others (1986); contact relations from Fiske and others (1963) and Vance and others (in press).

MΦvt Includes part of the Stevens Ridge Formation and the tuffs of Burnt Mountain, Bumping River, and Rattlesnake Creek. Age control for Stevens Ridge Formation consists of zircon fission-track and U-Pb ages from Vance and others (in press) that range from about 25 to about 27 m.y. Age for tuff of Burnt Mountain is from a zircon fission-track age of 24.6 ± 2.4 m.y. (Vance and others, in press). The tuff at Bumping River yielded zircon fission-track ages of about 27 to 28 m.y. (Vance and others, in press). Schreiber (1981) reported a zircon fission-track age of about 27 m.y. for the tuff at Rattlesnake Creek. Contact relations are from Fiske and others (1963), Schreiber (1981), Vance and others (in press), and Schasse (1987b, p. 21).

MΦvc Uncertain age and contact relations (Schasse, 1987b, p. 21).

MΦva Uncertain age and contact relations (Schasse, 1987b, p. 20).

Φvc Includes the Ohanapecosh Formation, tuffaceous rocks of Wildcat Creek, and sandstone of Spencer Creek. Age range based on K-Ar and fission-track dates from Vance and others (in press); contact relations from Ellingson (1959), Fiske and others (1963), Buckovic (1974), Swanson (1978), Winters (1984), Schasse (1987b), and Vance and others (in press).

Φvr Consists of the rhyolite flows of the Ohanapecosh Formation. Age from zircon fission-track determination of 30.4 ± 3.0 m.y. (Vance and others, in press). Contact relations from Fiske and others (1963).

Φva Includes lava flows of the Ohanapecosh Formation. Age range uncertain; flows are restricted to the upper part of the Ohanapecosh Formation (Fiske and others, 1963). (See unit Φvc.) Contact relations are from Fiske and others (1963) and Schasse (1987b, p. 24).

Φvb Consists of olivine basalt of Milk Creek. Age range uncertain; based on correlation with nearby dated units (Schasse, 1987b, p. 22-23; Swanson, 1978). Interbedded with tuff of Milk Creek (Swanson, 1978).

Φvt Consists of tuff of Milk Creek. Age range and contact relations uncertain; surrounded by landslide. Age and nature of contacts based on correlation with tuffaceous rocks of Wildcat Creek and sandstone of Spencer Creek (Swanson, 1978).

Ec$_2$ Consists of sandstone of the Naches Formation, Spiketon and Carbonado Formations of the Puget Group, undivided Puget Group sediments, Summit Creek sandstone, beds of Chambers Creek, and Lookout Creek sandstone. Age range for the Naches Formation from fission-track ages on interbedded rhyolites (Tabor and others, 1984). Age range for Spiketon and Carbonado based on correlation with type Puget Group (Gard, 1968; Buckovic, 1974) and on fossil leaves (Ellingson, 1959). Age range for Summit Creek based on 36-m.y. fission-track age for volcanic rocks just above sandstone and 44- and 46-m.y. fission-track ages for volcanic rocks below the unit (Vance and others, in press). For Chambers Creek unit, see column 8. Lookout Creek sandstone age range is from correlation with other Ec$_2$ units. Contact relations from Frizzell and others (1984), Gard (1968), Buckovic (1974), Vance and others (in press), Winters (1984), Schreiber (1981), and Clayton (1983).

Evt Consists of the welded tuff at Spencer Creek. Age range from zircon fission-track age of 41.8 ± 3.8 m.y. (Vance and others, in press). Contact relations from Swanson (1978).

Evc Age range is uncertain; the unit intertongues with rocks of the Puget Group (Schasse, 1987b, p. 26; Fisher, 1957, 1961). Contact relations from Fisher (1957, 1961) and Clayton (1983).

Evb Includes the basalt of Summit Creek. Age range from zircon fission-track ages of 42, 44, and 46 m.y. and zircon U-Pb model age of 55 m.y. (Vance and others, in press). Contact relations are from Ellingson (1959) and Clayton (1983).

Eva Age range and contact relations uncertain. Correlated with the Naches Formation (unit Ec2) by Bentley (1977) and Hammond (1980).

KJmct Consists of the chert-tuff subunit of the Russell Ranch Formation. Age range from radiolarian fauna (C. D. Blome, U.S. Geological Survey, written commun., 1986). Contact relations from Miller (1985).

KJm Consists of the chert-tuff unit of the Russell Ranch Formation. Age range from radiolarian fauna (C. D. Blome, U.S. Geological Survey, written commun., 1986). Contact relations from Miller (1985).

KJmv Consists of the pillowed greenstone in the clastic subunit of the Russell Ranch Formation. Age range uncertain and based solely on association with unit KJm. Contact relations from Miller (1985).

KJvb Consists of the eastern greenstone subunit of the Russell Ranch Formation. Age range is uncertain. Based on a melange model, the unit has the same age range as units KJm and KJmv (Miller, 1985). Contact relations are from Miller (1985).

pTvr Age range and contact relations uncertain; tentatively included in the Russell Ranch Formation by Miller (1985).

Jog Consists of part of the Indian Creek complex. Age range from zircon U-Pb date of 155 m.y.b.p. from pegmatite (Mattinson, 1972). Contact relations from Miller (1985).

Qian Includes plugs on Mount Rainier. Age range is uncertain and based on correlation with andesites of Mount Rainier (unit Qva) (Crandell and Miller, 1974), but rocks may be significantly younger.

QRian Unit not directly dated. Age range based on correlation of unit with Pliocene-Pleistocene volcanic rocks of the Goat Rocks area (Swanson and Clayton, 1983).

Rida Age range from Swanson and Clayton (1983).

Rian Age range uncertain (Swanson, 1978) and also based on K-Ar (biotite) age of 3.42 ± 0.19 m.y. and zircon fission-track age of 3.98 ± 0.22 m.y. from McNeil Peak (Clayton, 1983), to which Swanson (1978) suggested correlation of this unit.

Miq Age range from zircon fission-track determination of 11.5 ± 0.4 m.y. (Clayton, 1983).

Mia Includes quartz monzonite and granodiorite of the Bumping Lake pluton and undifferentiated intrusive bodies of Tatoosh pluton. Age range of 13-20 m.y.b.p. by correlation with the main phases of the Tatoosh pluton. (See unit Migd below.) Age of older part of unit is from a zircon fission-track determination of 25 m.y.b.p. on quartz monzonite of Bumping Lake pluton (Clayton, 1983) and 25.8-m.y. U-Pb age from zircon of a Tatoosh pluton sill (Mattinson, 1977).

Migd Includes granodiorite of the Tatoosh pluton and associated intrusions (White River pluton, Carbon River stock) and granodiorites of the Bumping Lake pluton. Age range (from K-Ar dates) is from 13 to 20 m.y. (Fiske and others, 1963; Mattinson, 1977; Frizzell and others, 1984). See also Schasse (1987b) for more details.

Mig Includes granite of the White River pluton and quartz monzonite of the Tatoosh pluton. Age range is from relation to units Mia and Migd from Thompson (1983).

Miv Consists of the Skyscraper Mountain complex. Age range uncertain; range shown is from Thompson (1983).

MΦiv Consists of the Mount Aix volcanic complex. Age range based in part on interpretation of unit as a caldera and source for unit MΦvt. Unit also yielded zircon fission-track ages of about 28 m.y. (Schreiber, 1981) and about 26 m.y. (Vance and others, in press).

Jiq Includes directionless to weakly foliated plutonic rocks of the Indian Creek complex and the Peninsula tonalite. Age range is from correlation with unit Jog (Miller, 1985). Unit yielded zircon fission-track ages of 132 or 152.5 m.y. (the two dates result from using different calibration techniques; Clayton, 1983).

Column 7—South half of the Snoqualmie Pass and southwest quarter of the Wenatchee 1:100,000 Quadrangles

See Frizzell and others (1984) and Tabor and others (1982, 1984) for further stratigraphic details.

Qa Described as Holocene deposits in Frizzell and others (1984, p. 14) and Tabor and others (1982, p. 21).

Qvl Consists of the Osceola Mudflow. See column 6 for details of age range.

Qad Includes part of the Lakedale Drift. Age range of about 12,000 to 18,000 yr b.p. from Porter (1976).

Qao Includes part of the Lakedale Drift. Has same age range as unit Qad.

Qgo Includes part of the Vashon Drift. Age range of about 13,500 to 15,000 yr b.p. from Porter (1976).

Qgd Includes part of the Vashon Drift. Age range of about 13,500 to 15,000 yr b.p. from Porter (1976).

Qap Consists of part of the Kittitas Drift and Lookout Mountain Ranch Drift. The Kittitas has an approximate age range of 130,000 to 140,000 yr b.p. suggested by R. B. Waitt (*in* Tabor and others, 1982). The Lookout Mountain Ranch Drift has been tentatively assigned a 0.75-m.y. age by Waitt (1979).

Qapo Consists of part of the Kittitas Drift. Age range of 130,000 to 140,000 yr b.p. is suggested by R. B. Waitt (*in* Tabor and others, 1982, p. 17).

Qva Consists of the andesites of Mount Rainier. Age range is based on plagioclase and whole-rock K-Ar determinations of 600,000 and 320,000 yr b.p. (Crandell and Miller, 1974, p. 17) outside the column area.

Qvb Age range is uncertain, but the unit is normally magnetized and hence probably younger than about 690,000 yr (Hammond, 1980, p. 18). Age range shown is based on correlation with andesite of Mount Rainier flows (unit Qva).

Rc Consists of the Thorp Gravel. Age range is based in part on zircon fission-track and hornblende K-Ar ages ranging from about 3.8 to 4.4 m.y. (R. B. Waitt, *in* Tabor and others, 1982, p. 17). Upper age limit is uncertain. Contact relations are from Tabor and others (1982).

Mc Consists of the Ellensburg Formation. Age range is based on interbedding of unit with Grande Ronde Basalt (Mv_g). Contact relations are from Tabor and others (1982).

Mv_g Consists of the R_2, and N_2 magnetostratigraphic units of the Grande Ronde Basalt. Grande Ronde flows are bracketed by ages between 17.0 and 15.5 m.y. (Reidel and others, 1987) by K-Ar and ^{40}Ar-^{39}Ar age determinations outside the column area. Contact relations are from Tabor and others (1982).

Mva Consists of the Fifes Peak Formation and volcanic rocks of Eagle Gorge. K-Ar ages and zircon fission- track ages from the Fifes Peak Formation indicate a range of about 17 to 24 m.y. (Frizzell and others, 1984, p. 19-21). Zircon fission-track ages in the adjoining Mount Rainier column (Vance and others, in press) suggest base of unit is somewhat older. Pronounced angular unconformity between the Fifes Peak and overlying 17-15.5-m.y.-old Grande Ronde basalt indicates top of unit may be somewhat older than 17 m.y. Contact relations are from Frizzell and others (1984).

Mvr Consists of the White River rheoignimbrite. Age range is from interbedded relationship with the Fifes Peak Formation (unit Mva) and dated intrusive rhyolite (unit Mir) (Frizzell and others, 1984, p. 20). Contact relations are from Frizzell and others (1984).

Mvc Age range based on unit's interbedded relationship with dated portion of Fifes Peak Formation. (See unit Mva). Contact relations from Frizzell and others (1984, p. 21).

Mvt Consists of part of the volcanic rocks of Eagle Gorge and the Stevens Ridge Formation. Age range is based on K-Ar and fission-track ages of about 20 to 24 m.y. (Frizzell and others, 1984, p. 21).

Φvc Includes the volcanic rocks of Huckleberry Mountain and the Ohanapecosh Formation. Age range of about 35 to about 25 m.y.b.p. is indicated by K-Ar and fission-track determinations (Frizzell and others, 1984, p. 23-25; Tabor and others, 1984). Contact relations are from Frizzell and others (1984).

Ec_2 Consists of undivided Puget Group, part of the Naches Formation, and the Roslyn Formation. Age range for undivided Puget Group is based on megaflora referable to the Franklinian, Fultonian, Ravenian, and Kummerian Stages (Wolfe, 1968). Palynomorph assemblage in the Roslyn indicates a late Eocene age (Newman, 1981, p. 56). Age range for Naches is based partly on K-Ar and zircon fission-track ages ranging from about 40 to 44 m.y., partly on megafloral data indicating a late Eocene age, and partly on regional correlation with similar, better dated units in the Cascade Mountains and Puget Lowland (Tabor and others, 1984, p. 35-37, fig. 7).

Ev Consists of part of the Naches Formation. Age range is based on correlation with unit Ec_2, and on radiometric dates from interbedded units Evb and Evr. Age range and contact relations are from Frizzell and others (1984) and Tabor and others (1984).

Evr Consists of part of the Naches Formation. Age range is based on zircon fission-track ages of about 40 to 44 m.y. (Frizzell and others, 1984, p. 28; Tabor and others, 1984, table 2) and on arguments that the rhyolites are coeval with the upper Eocene Roslyn Formation (Tabor and others, 1982, p. 9). Contact relations are from Frizzell and others (1984) and Tabor and others (1982).

Evb Column contains two distinct units. Younger unit consists of part of the Naches Formation. Whole-rock K-Ar age determinations indicate an age of 40 to 43 m.y. (Frizzell and others, 1984, p. 28, table 1; Tabor and others, 1984, table 2); contact relations are from Frizzell and others (1984). The older unit consists of the Teanaway Formation and basalt of Frost Mountain. Age of about 47 m.y. for the Teanaway and correlative basalt of Frost Mountain is indicated by K-Ar determinations (Tabor and others, 1984, table 1). Contact relations are from Tabor and others (1982).

Eva Consists of the Taneum Formation. The age range is based on two zircon fission-track dates of about 52 and about 46 m.y.b.p. reported by Tabor and others (1984). Contact relations are from Tabor and others (1984, 1982).

Ec_1 Consists of the Manastash and Swauk Formations. Early to middle Eocene age of the Swauk is from fossil pollen (Newman, 1981) and zircon fission-track ages of about 52 m.y. from an interbedded unit outside the map area (Silver Pass Volcanic Member; Tabor and others, 1984). Correlation of Manastash with Swauk is somewhat uncertain and based on fossil pollen (Newman, 1977) and regional structural arguments (Tabor and others, 1984, p. 38). Contact relations are from Tabor and others (1984, 1982).

Evt Age range and contact relations are uncertain because unit is surrounded by landslides or intrusive rocks. It is correlated by Tabor and others (1982) with the 52-m.y.-old Silver Pass Volcanic Member of the Swauk Formation.

Jog Consists of the tonalite gneiss of Hicks Butte. Age based on roughly concordant zircon U-Pb ages of about 153 m.y. (Frizzell and others, 1984).

Jsh Consists of parts of the Easton Schist. Probable late Jurassic protolith age is based on correlation of unit (Frizzell and others, 1984, p. 34; Tabor and others, 1982, p. 5) with Shuksan Metamorphic Suite (Brown and others, 1982, p. 1095). Contact relations with older units are uncertain.

Jph Consists of parts of the Easton Schist. Age range and contact relations are the same as unit Jsh.

pJsc Consists of the Lookout Mountain Formation. Age range and contact relations uncertain. Unit is intruded by 157-m.y.-old quartz diorite (unit Jiq; Frizzell and others, 1984).

pJam Age range and contact relations uncertain and based on tentative correlation with unit pJsc.

Mvi_g Consists of an invasive flow of Grande Ronde Basalt magnetostratigraphic unit R_2. Age range same as unit Mv_g.

Migd Consists of the Carbon River stock. Age range from biotite and hornblende K-Ar ages of about 17 and 19 m.y. (Frizzell and others, 1984, p. 17).

Mir — Consists of part of the Clear West complex. Age range from K-Ar whole-rock date of 19 m.y.b.p. (Hartman, 1973, p. 30) and zircon U-Pb ages of about 22-23 m.y. (Mattinson, 1977, p. 1512).

Eib — Two units are represented. Younger unit is probably related to volcanism of the Naches Formation (units Evb and Evr, Frizzell and others, 1984, p. 25). Older unit may be related to the 47-m.y.-old Teanaway Formation (older unit Evb above).

Eida — Consists of the andesite of Peoh Point. Age range is uncertain because unit is virtually surrounded by landslides. Tabor and others (1982, p. 11) suggest that the intrusion represents a last pulse of Taneum Formation volcanism (unit Eva).

Jiq — Consists of the Quartz Mountain quartz diorite. Age range from relatively concordant U-Pb ages from zircons of about 157 m.y. (Frizzell and others, 1984, p. 33).

Column 8—Mount Adams and Hood River 1:100,000-scale Quadrangles

See Korosec (1987a,b) for further age dates and stratigraphic information.

Qa — Assumed to be largely of Holocene age; however, may contain some Pleistocene glacial deposits (Korosec, 1987a,b).

Qd — Unit is younger than flood deposits of glacial Lake Missoula (units Qfg and Qfs below). The dunes are active and unstable and are assumed to range in age through the entire Holocene.

Qvc — Age range from Hildreth and others (1983) for Mount Adams deposits.

Qvl — Consists of the Trout Lake mudflow, which yielded a radiocarbon age of 5,070 ± 260 yr (Hopkins, 1976).

Qfs — Age range of 12,700 to 15,300 yr b.p. from Waitt (1985, p. 1284).

Qfg — Same age range as for unit Qfs.

Qad — Consists of part of the Evans Creek Drift and McDonald Ridge drift. Age range is from Hammond (1980), Crandell and Miller (1974), and Porter (1976). Holocene glacial deposits of Mount Adams are not shown.

Qao — Consists of outwash of the Evans Creek Drift. Age range same as for unit Qad above.

Qvb — Includes basalt of the Indian Heaven volcanic field. Age range and contact relations are from multiple sources detailed in Korosec (1987a,b). Youngest flows are of mid-Holocene age and oldest flows of possible late Pliocene age (Hammond and Korosec, 1983).

Qva — Includes andesites of Mount Adams. Age range and stratigraphic relations for Mount Adams from Hildreth and others (1983). Age range for basaltic andesite flows of the Indian Heaven volcanic field is from sources detailed in Korosec (1987a,b).

Qvd — Age range of dacite from K-Ar ages of 470,000 ± 40,000 and 460,000 ± 20,000 yr reported by Hildreth and others (1983).

Qap — Consists of the Hayden Creek Drift and the White Salmon drift. Age range of Hayden Creek Drift from Hammond (1980) and Porter (1976). The White Salmon is correlated with the Hayden Creek by Hammond (1980).

QPlva — Age range is from andesite of the Goat Rocks area; approximate age range is 1 to 3 m.y.b.p. (Clayton, 1983; Swanson and Clayton, 1983) in column 6.

QPlvb — Includes the basalt of the Simcoe Mountains, basalt of Lincoln Plateau, and basalt of Balch Lake. Age range for basalt of the Simcoe Mountains is 1.0 to 4.7 m.y.b.p., with most flows confined to 2.5 to 4.5 m.y.b.p. (Korosec, 1987b; Anderson, 1987a,b). The basalt of Balch Lake may have originated in the Simcoe Mountains volcanic field (Newcomb, 1969; Korosec, 1987b) and is assigned the same age range. Age range of the basalt of Lincoln Plateau is uncertain but that unit is possibly younger than the basalt of the Simcoe Mountains (Hammond, 1980; Korosec, 1987a).

QPlvd — Age range uncertain. Correlated in part with basalt of the Simcoe Mountains (unit QPlvb) (Korosec, 1987b).

QPlc — Consists of the sedimentary deposits of Swale Creek valley. The unit is overlain by 0.9-m.y.-old lava flow (Shannon and Wilson, 1973) in column 9. Age of the Swale Creek unit is uncertain.

Plvr — Includes the Devils Horns rhyolite. In column 6, age range of Devils Horns unit from zircon fission-track dates of about 3 m.y.b.p. (Clayton, 1983). Undated rhyolites in column area (Korosec, 1987a) are assumed to be Pliocene, possibly related to the Devils Horns rhyolite.

Plvt — Includes the tuff at Midway. K-Ar ages are 3.6 ± 0.4 and 3.7 ± 0.4 m.y. (Hammond, 1980). Undated tuffs in column area (Korosec, 1987a) are assumed to be Pliocene, possibly related to the Devils Horns rhyolite (unit Plvr).

Plc — Age range uncertain. Overlain by unit Plvr (Korosec, 1987a, p. 23).

Mc — Includes the Ellensburg Formation and the Dalles Formation. Contact relations for the Dalles Formation are from Newcomb (1966). Leaf fossil data summarized by Newcomb (1966) suggest a late Miocene to early Pliocene age, but K-Ar ages of 10.8 and 15.2 m.y. for units above and within the Dalles Formation outside the column area indicate only a late Miocene age. The Ellensburg Formation is overlain by unit QPlvb and overlies the 14.5-m.y.-old Priest Rapids Member of the Wanapum Basalt (unit Mv_w; Korosec, 1987b, p. 22- 23).

Mv_s — Consists of the Pomona Member of the Saddle Mountains Basalt. Dated by K-Ar at about 12 m.y.b.p. outside the column area (McKee and others, 1977). Contact relations are from Bentley and others (1980) and Anderson (1987a).

Mv_w — Consists of the Priest Rapids, Roza, and Frenchman Springs Members of the Wanapum Basalt. Age of the Priest Rapids Member is about 14.5 m.y. (Reidel, 1984, fig. 2). The Frenchman Springs Member has an average K-Ar age of about 15.3 m.y. (Beeson and others, 1985). The Roza Member lies between the Frenchman Springs and Priest Rapids Members.

Mv_g Consists of the N_2, R_1, and N_1 magnetostratigraphic units of the Grande Ronde Basalt. Unit's age bracketed by K-Ar and ^{40}Ar-^{39}Ar dates between 17.0 and 15.5 m.y.b.p. outside column area. Contact relations from Korosec (1987a,b).

Mvd The unit's upper age limit was determined by a whole-rock K-Ar date of 15.6 ± 0.2 m.y.b.p. (Phillips and others, 1986). Age range for base from correlation with volcanic rocks of Council Bluff. (See unit Mva; Korosec, 1987a.) Contact relations from Korosec (1987a).

Mvb Consists of two units. Upper Miocene flows have a K-Ar age of 12.9 ± 0.3 m.y. (Phillips and others, 1986); lower Miocene flows have K-Ar ages of about 20 to 24 m.y. (Phillips and others, 1986; Evarts and Ashley, 1984). Contact relations are from Korosec (1987a,b).

Mvt Age range and contact relations from Korosec (1987a, p. 26) and Korosec (1987b, p. 27). K-Ar ages range from about 17 to about 26 m.y. (Hammond, 1980; J. G. Smith, U.S. Geological Survey, oral commun., 1986).

Mcg Consists of the Eagle Creek Formation. Age range and contact relations from Wise (1961) and Hammond (1980). The unit rests unconformably on upper Oligocene volcaniclastic rocks (unit Φvc) and is unconformably overlain by middle Miocene Grande Ronde Basalt (Mv_g).

Mva Includes the volcanic rocks of Council Bluff and volcanic rocks of Stevenson Ridge. Age range and contact relations from Korosec (1987a, p. 25, 27) and Korosec (1987b, p. 26-27). Council Bluff has K-Ar ages ranging from 20 to 27 m.y. Stevenson Ridge flows are underlain by lower Miocene tuffs (Mvt) and overlain by 21-23-m.y.-old basalt flows dated by K-Ar (Mvb).

Mvc Age range and contact relations from Korosec (1987a,b) and Berri and Korosec (1983). Unit is stratigraphically bounded by upper Oligocene volcaniclastic rocks (unit Φvc) and K-Ar-dated lower Miocene flows (Mvb) and tuffs (Mvt).

MΦv Age range and contact relations uncertain. Possibly includes parts of the Ohanapecosh Formation (Φvc and Φva) and the volcanic rocks of Council Bluff (Mva; Korosec, 1987a).

MΦva Age range and contact relations uncertain; described by Korosec (1987a). Interbedded with unit MΦvc.

MΦvc Age range and contact relations uncertain; described by Korosec (1987a). Underlies early Miocene tuffs and flows (units Mvt and Mva).

MΦvt Age range and contact relations uncertain; described by Korosec (1987a,b). Correlated with unit MΦvc above.

Φvc Includes the Ohanapecosh Formation. Upper age limit of the Ohanapecosh is determined from K-Ar dates on interbedded flows (Φva) and overlying tuffs (Mvt). Lower age limit is determined from interbedding of unit with upper Eocene sedimentary rocks (Ec_2). Additional age control is from Vance and others, (in press) outside of column area. Other unnamed strata mapped as Φvc were correlated with Ohanapecosh Formation. Contact relations are from Korosec (1987a,b).

Φva Consists of flows interbedded with the upper Ohanapecosh Formation (Φvc) and flows capping unit MΦvc (Korosec, 1987a,b). Dated by whole-rock K-Ar at 30.1 ± 2.2 m.y.b.p. (Phillips and others, 1986).

Φvt See unit Φvt on column 4.

Ec_2 Consists of the beds of Chambers Creek. A megaflora collection by Winters (1984) near base of unit is referred to the Franklinian and lower Ravenian megaflora zones (middle Eocene) of Wolfe (1981). Winters (1984) reports a zircon fission-track age of 35.9 ± 0.7 m.y. from an altered vitric tuff near the top of unit.

Ꝑiq Consists of the Wind Mountain quartz diorite. Age range based on K-Ar age date of 4.9 ± 0.1 m.y.b.p. (Phillips and others, 1986).

Ꝑida Includes the Hauk Butte dacite and related domes or stocks (Korosec, 1987b). Age is based on a K-Ar date of 4.8 ± 0.1 m.y.b.p. (Phillips and others, 1986).

Mida Age from a fission-track age of about 20 m.y. (J. A. Vance, Univ. of Washington, oral commun., 1986) from a large diorite stock at Sunrise Peak.

Miq Includes the McCoy Creek quartz diorite. Age from a K-Ar date on sericite of 24.0 ± 0.9 m.y.b.p. (Armstrong and others, 1976).

Column 9—West half of the Yakima, west half of the Toppenish, and northwest portion of the Goldendale 1:100,000-scale Quadrangles

See Walsh (1986a,b) and Phillips and Walsh (1987) for further stratigraphic details.

Qa Assumed to be of Holocene age.

Qoa Age range uncertain. Consists dominantly of dissected alluvial fans lying above flood deposits of glacial Lake Missoula (units Qfs and Qfg). Considered by Bentley and Campbell (1983a,b) to be partly coeval with loess (unit Ql). Minor portion of unit on Toppenish Ridge dated by Campbell and Bentley (1981) at about 500 to 600 yr b.p.

Ql Age range uncertain. Tentatively considered by Bentley and others (1980) to be as old as Pliocene and as young as unit Qoa.

Qfs Age range of 12,700 to 15,300 yr b.p. from Waitt (1985, p. 1284).

Qfg Same age range as for unit Qfs.

Qt Inferred to include 10,000-140,000-yr-old Kittitas and Lakedale Drifts based on mapping in column 7 area (Tabor and others, 1982).

Qvb Age range based on K-Ar age of about 0.9 m.y. for basalt flow at Haystack Butte (Shannon and Wilson, 1973).

Qva Consists of the Tieton Andesite, dated by K-Ar at 1.0 ± 0.1 m.y. (Swanson, 1978).

QꝐvb Consists of the volcanic rocks of Simcoe Mountains. Age range for most of unit is based on K-Ar ages of about 3 to 4.2 m.y. (Phillips and others, 1986). Geomorphology and reversed magnetic polarity suggest a mid-Pleistocene upper age limit (Anderson, 1987a).

QPlc — Includes the Swale Creek valley sedimentary deposits. Age range uncertain. Swale Creek deposits are overlain by a 0.9-m.y.-old basalt flow (unit Qvb), and younger deposits contain clasts probably derived from mostly Pliocene volcanic rocks of Simcoe Mountains (units QPlvb, Plida, and Plvr) (Anderson, 1987a). Contact relations are from Anderson (1987a) and Newcomb (1969).

Plc — Consists of the Thorp Gravel. Same age range as for unit Plc in column 7.

Plvr — Consists of part of the volcanic rocks of the Simcoe Mountains. Age range from K-Ar age of 4.06 ± 0.05 m.y. (Phillips and others, 1986) and from interbedding with basalt flows of unit QPlvb (Anderson, 1987a).

Mc — Consists of the Ellensburg Formation. Age range of base from interfingering with flows of the Columbia River Basalt Group. (See units Mv_s, Mv_w, and Mv_g below.) Upper age limit of unit is uncertain. It is unconformably overlain by Pliocene volcanic rocks of Simcoe Mountains (unit QPlvb). Top of unit is constrained by contact with Pliocene Thorp Gravel (Anderson, 1987b; Bentley and Campbell, 1986).

Mv_s — Consists of the Elephant Mountain, Pomona, Umatilla, Wilbur Creek, and Asotin Members of the Saddle Mountains Basalt. Units dated by K-Ar at about 10.5, 12.0, 13.5, 13-12.7, and 13 m.y.b.p., respectively, outside the column area (McKee and others, 1977; S. P. Reidel, Westinghouse Hanford Co., oral commun., 1986). Contact relations are from Bentley and others (1980), Bentley and Campbell (1983a,b).

Mv_w — Consists of the Priest Rapids, Roza, and Frenchman Springs Members of the Wanapum Basalt. The Priest Rapids Member is about 14.5 m.y. old (Reidel, 1984, fig. 2). The Frenchman Springs Member has an average K-Ar age of about 15.3 m.y. (Beeson and others, 1985). The Roza Member lies between the Frenchman Springs and Priest Rapids Members. Contact relations are from Anderson (1987b), Bentley and others (1980), and Bentley and Campbell (1983a,b).

Mv_g — Consists of the N_1, R_2, and N_2 magnetostratigraphic units of the Grande Ronde Basalt. K-Ar and ^{40}Ar-^{39}Ar ages from outside the column area bracket the Grande Ronde Basalt between 17.0 and 15.5 m.y. (Reidel, 1984).

Mva — Consists of part of the Fifes Peak Formation. Age range from K-Ar dates is about 16 to 25 m.y.b.p. (Vance and others, in press). Contact relations are from Swanson (1966, 1978) and Carkin (1985).

Plida — Age range uncertain. Overlies basalt flows of unit QPlvb and rhyolite of unit Plvr (Anderson, 1987b).

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ERRATA

On the geologic map, Sheet 1:

The fault at the upper end of the North Fork Tieton River is shown as displacing Rvr against Φvc; it should have shown Rvr on the down-dropped block. See Schasse (1987b) for correct depiction.

In the Descriptions of Map Units, Sheet 2:

In unit Mvi_g, for "consists of", read "includes". In units ΦEvc, ΦEvt, Ev, Evc, and Miqm, for "includes", read "consists of".

In the Correlation Diagram, Sheet 2, the names Goble Volcanics and Hatchet Mountain Formation should be leadered to the same box of unit ΦEva because we consider these two units to be synonymous. See unit ΦEvt for an example of correct portrayal.

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

Geologic Map GM-34
Washington Division of Geology and Earth Resources
Raymond Lasmanis, State Geologist

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Weldon W. Rau, Biostratigrapher

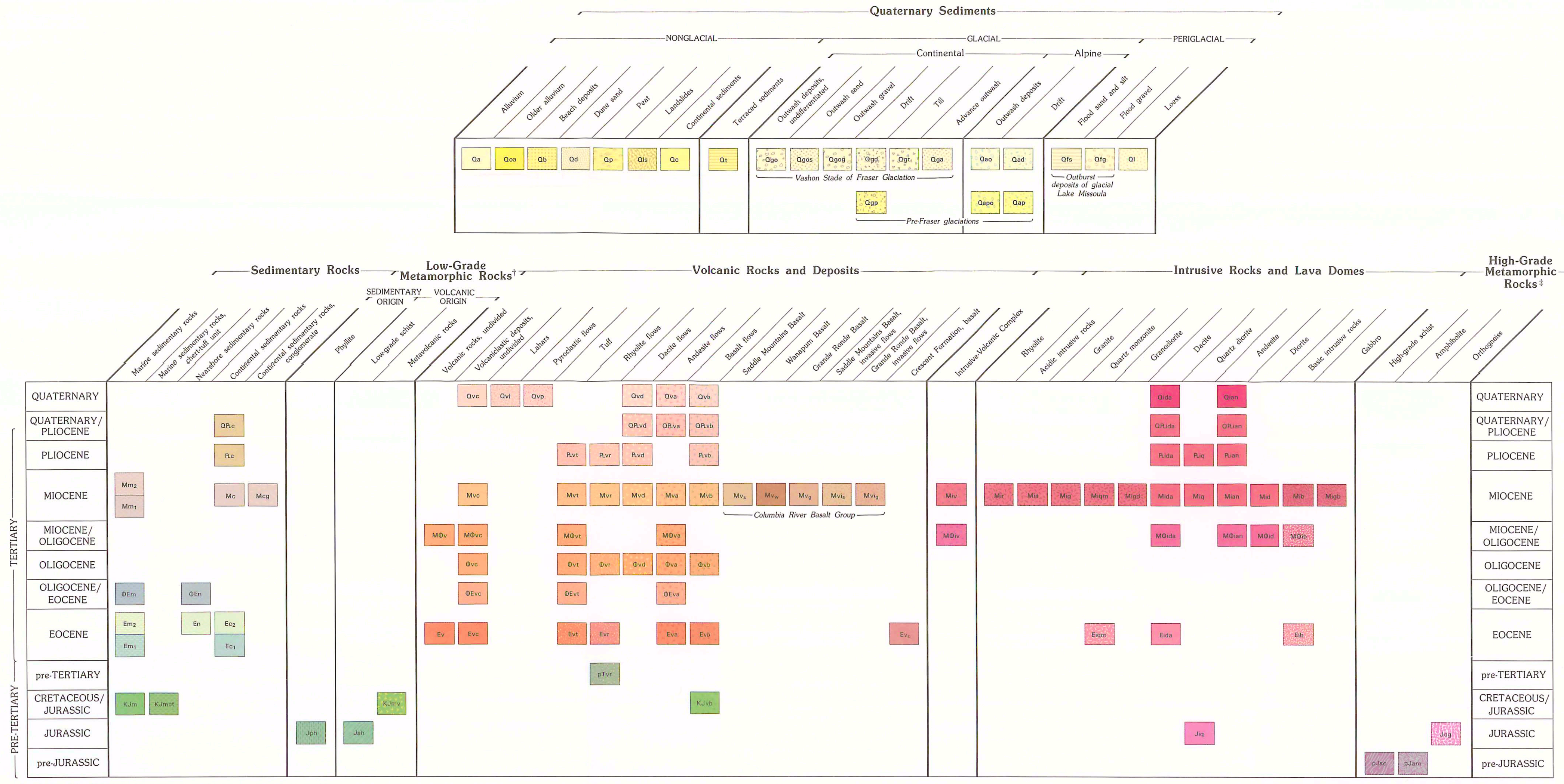
GEOLOGIC MAP OF WASHINGTON—SOUTHWEST QUADRANT

by

Timothy J. Walsh, Michael A. Korosec, William M. Phillips, Robert L. Logan, and Henry W. Schasse

1987

Key To Geologic Units*



* See Sheet 2 for chronologic and stratigraphic relationships and detailed unit descriptions.
† greenschist and blueschist facies
‡ amphibolite and granulite facies

Geologic Symbols

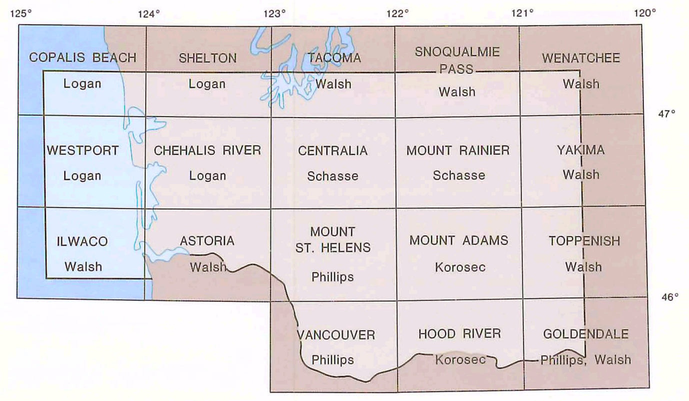
- Contact
- Scratch boundary—Indicates unreconciled differences at source map boundaries
- Fault—Dashed where uncertain; dotted where concealed
- Dip-slip fault—Bar and ball on downthrown side; dashed where uncertain; dotted where concealed
- Strike-slip fault—Showing relative horizontal movement; dashed where uncertain; dotted where concealed
- Thrust fault—Sawteeth on upper plate; dashed where uncertain; dotted where concealed
- Anticline—Showing direction of plunge; dashed where uncertain; dotted where concealed
- Syncline—Showing direction of plunge; dashed where uncertain; dotted where concealed
- Monocline—Dashed where uncertain; dotted where concealed
- Maximum extent of the Puget Lobe of the Fraser Glaciation
- Dike
- Volcanic vent—Pliocene through Holocene
- Mylonite zone
- Tectonic zone

SCALE 1:250,000

Contour Interval 200 Meters
Supplementary Contours at 100 Meters Above Sea Level and 100 Meters Below Sea Level
National Geodetic Vertical Datum of 1929

Base compiled from U.S. Geological Survey 1:100,000-scale topographic quadrangles dated 1975-84
Projection and 10,000-meter grid, zone 10, Universal Transverse Mercator
100,000-foot grid ticks based on Washington coordinate system, south zone
1927 North American Datum
Pacific Ocean bathymetry from Wagner and others (1986)
Puget Sound bathymetry from U.S. Navy (1953)
Cartographic design and production by Nancy Eberle Herman, Donald W. Hiller, and Keith G. Ikerd

Compilation Responsibility by 1:100,000-scale Quadrangle



Quadrant Location

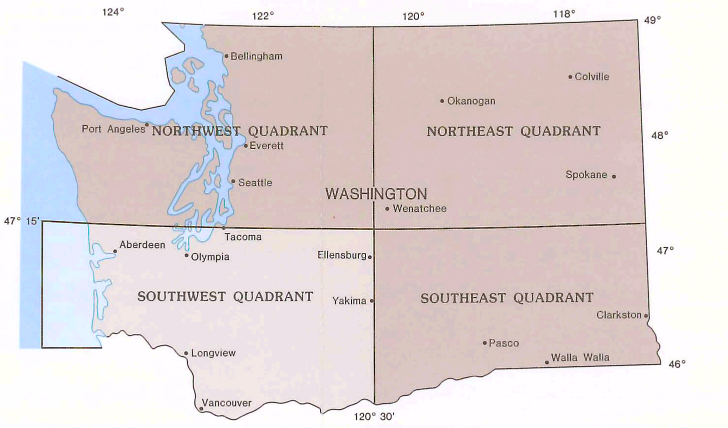


Table of Contour Value Equivalents

Meters	Feet
100	328
200	656
400	1312
600	1968
800	2625
1000	3281
1200	3937
1400	4593
1600	5249
1800	5905
2000	6562
2200	7218
2400	7874
2600	8530
2800	9186
3000	9842
3200	10,499
3400	11,155
3600	11,811
3800	12,467
4000	13,123
4200	13,779

To convert meters to feet, multiply by 3.2808
To convert feet to meters, multiply by 0.3048

DESCRIPTIONS OF MAP UNITS

SEDIMENTS AND SEDIMENTARY ROCKS

QUATERNARY SEDIMENTS

Nonglacial

Periglacial

Glacial

PLEISTOCENE-PLIOCENE SEDIMENTS

Continental

PLIOCENE SEDIMENTS

Continental

MIOCENE SEDIMENTARY ROCKS

Marine

Continental

OLIGOCENE-EOCENE SEDIMENTARY ROCKS

Marine

Nearshore

EOCENE SEDIMENTARY ROCKS

Marine

Nearshore

Continental

CRETACEOUS AND JURASSIC SEDIMENTARY ROCKS

Marine

METAMORPHIC ROCKS

JURASSIC METAMORPHIC ROCKS

PRE-JURASSIC METAMORPHIC ROCKS

VOLCANIC ROCKS AND DEPOSITS

QUATERNARY VOLCANIC ROCKS AND DEPOSITS

Lava Flows

Volcaniclastic Deposits

PLEISTOCENE-PLIOCENE VOLCANIC ROCKS

Lava Flows

PLIOCENE VOLCANIC ROCKS

Lava Flows

Volcaniclastic Rocks

MIOCENE VOLCANIC ROCKS

Lava Flows

Volcaniclastic Rocks

Flows of Miocene Columbia River Basalt Group

Yakima Basalt Subgroup

MIOCENE-OLIGOCENE VOLCANIC ROCKS

Undivided

Lava Flows

Volcaniclastic Rocks

OLIGOCENE VOLCANIC ROCKS

Lava Flows

Volcaniclastic Rocks

OLIGOCENE-EOCENE VOLCANIC ROCKS

Lava Flows

Volcaniclastic Rocks

INTRUSIVE ROCKS AND LAVA DOMES*

QUATERNARY INTRUSIVE ROCKS

Intermediate

PLEISTOCENE-PLIOCENE INTRUSIVE ROCKS

Intermediate

PLIOCENE INTRUSIVE ROCKS

Intermediate

MIOCENE INTRUSIVE ROCKS

Acidic

Intermediate

Basic

Intrusive-Volcanic Complex

MIOCENE-OLIGOCENE INTRUSIVE ROCKS

Intermediate

Basic

Intrusive-Volcanic Complex

EOCENE INTRUSIVE ROCKS

Acidic

Basic

Intermediate

JURASSIC INTRUSIVE ROCKS

Intermediate

* See pamphlet for intrusive rock classification.

EOCENE VOLCANIC ROCKS

Undivided

Lava Flows

Volcaniclastic Rocks

Crescent Formation Lava Flows and Volcaniclastic Rocks

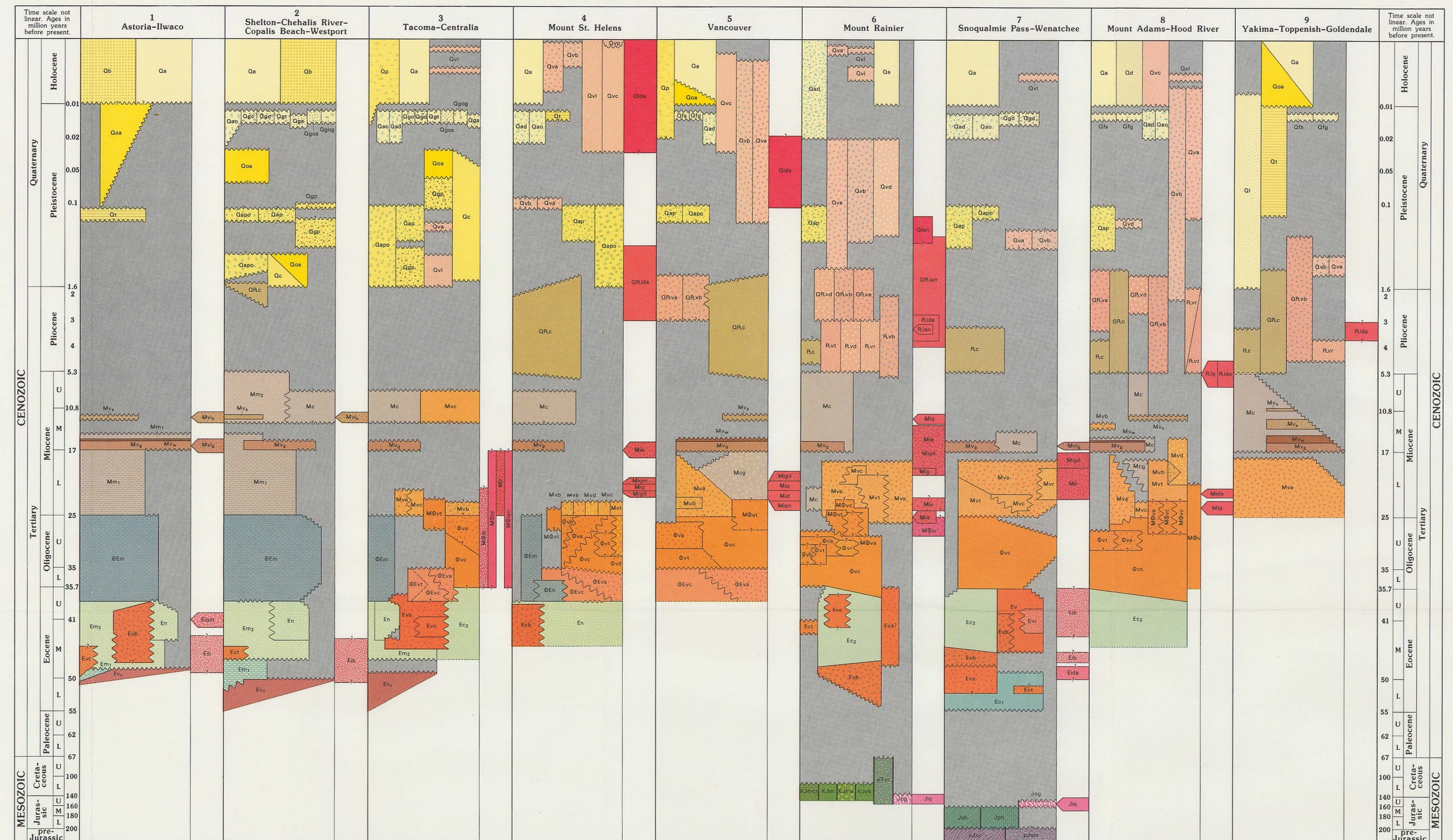
PRE-TERTIARY VOLCANIC ROCKS

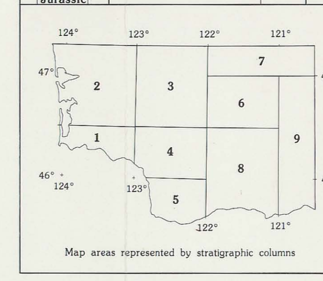
Lava Flows

CRETACEOUS-JURASSIC VOLCANIC ROCKS

Lava Flows

STRATIGRAPHIC COLUMNS





NOTES

CORRELATION DIAGRAM

Geologic Map of Washington — Southwest Quadrant
Washington Division of Geology and Earth Resources
Geologic Map GM-34
Sheet 2

LIST OF NAMED UNITS