GEOLOGIC MAP OF WASHINGTON-SOUTHWEST QUADRANT

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TIMOTHY J. WALSH, MICHAEL A. KOROSEC,
WILLIAM M. PHILLIPS, ROBERT L. LOGAN, and HENRY W. SCHASSE

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-34

1987

WASHINGTON STATE DEPARTMENT OF
Natural Resources

Brian Boyle - Commissioner of Public Lands
Art Stearns - Supervisor

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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

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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.

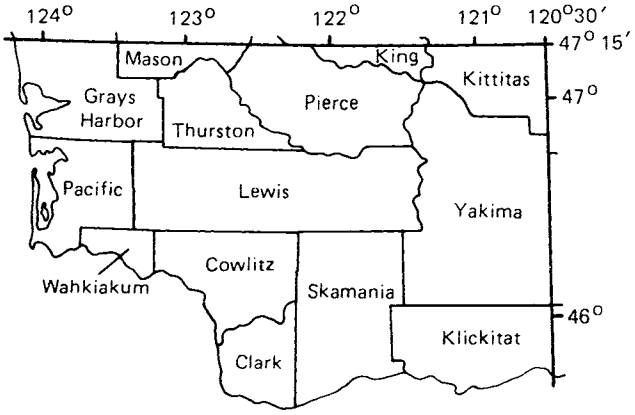

Figure 1.-Counties in southwestern Washington.

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).

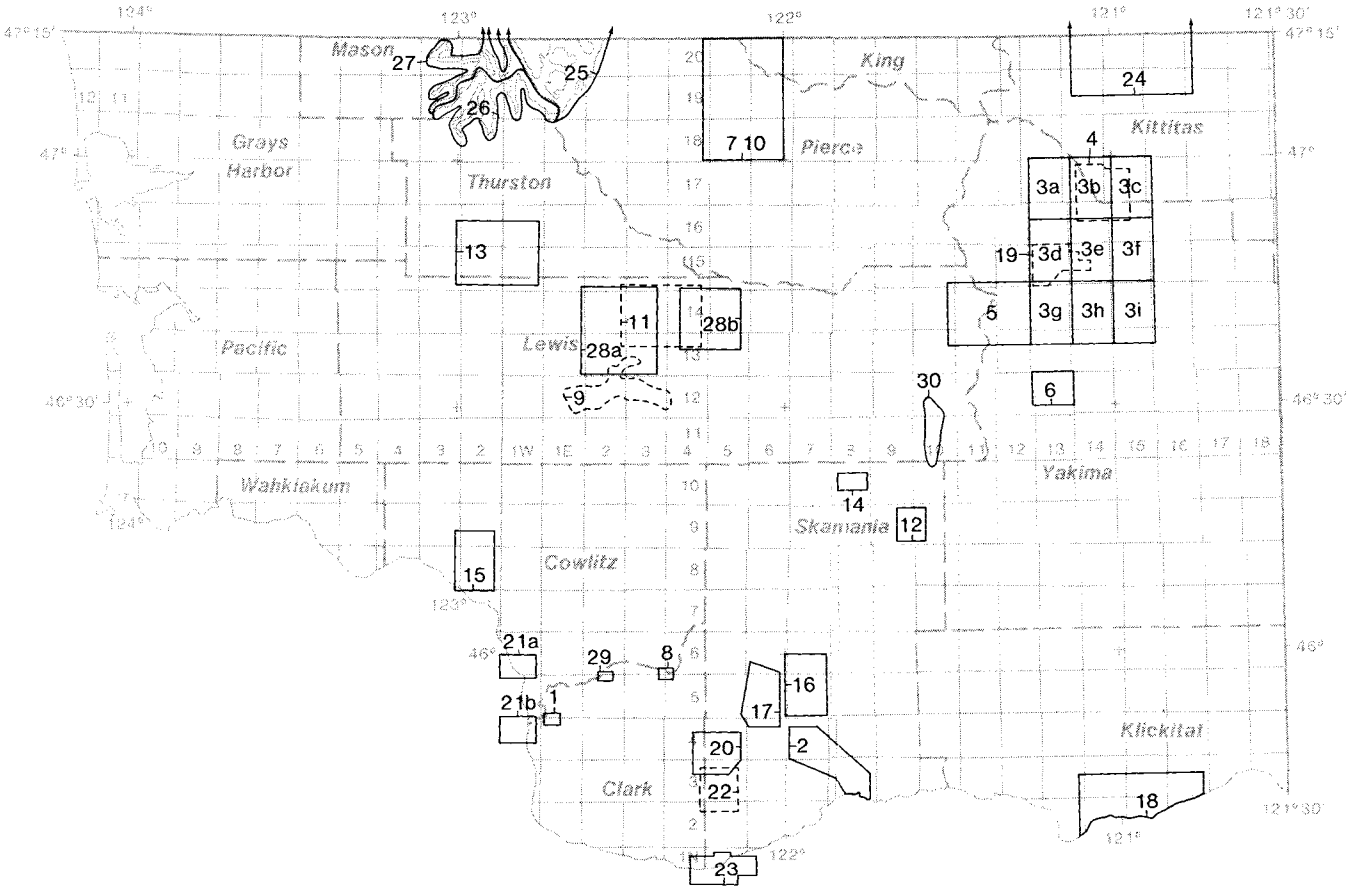

Figure 2.-Index to sources of map data, scales 1:1,200 through 1:24,000 and source references without maps.

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

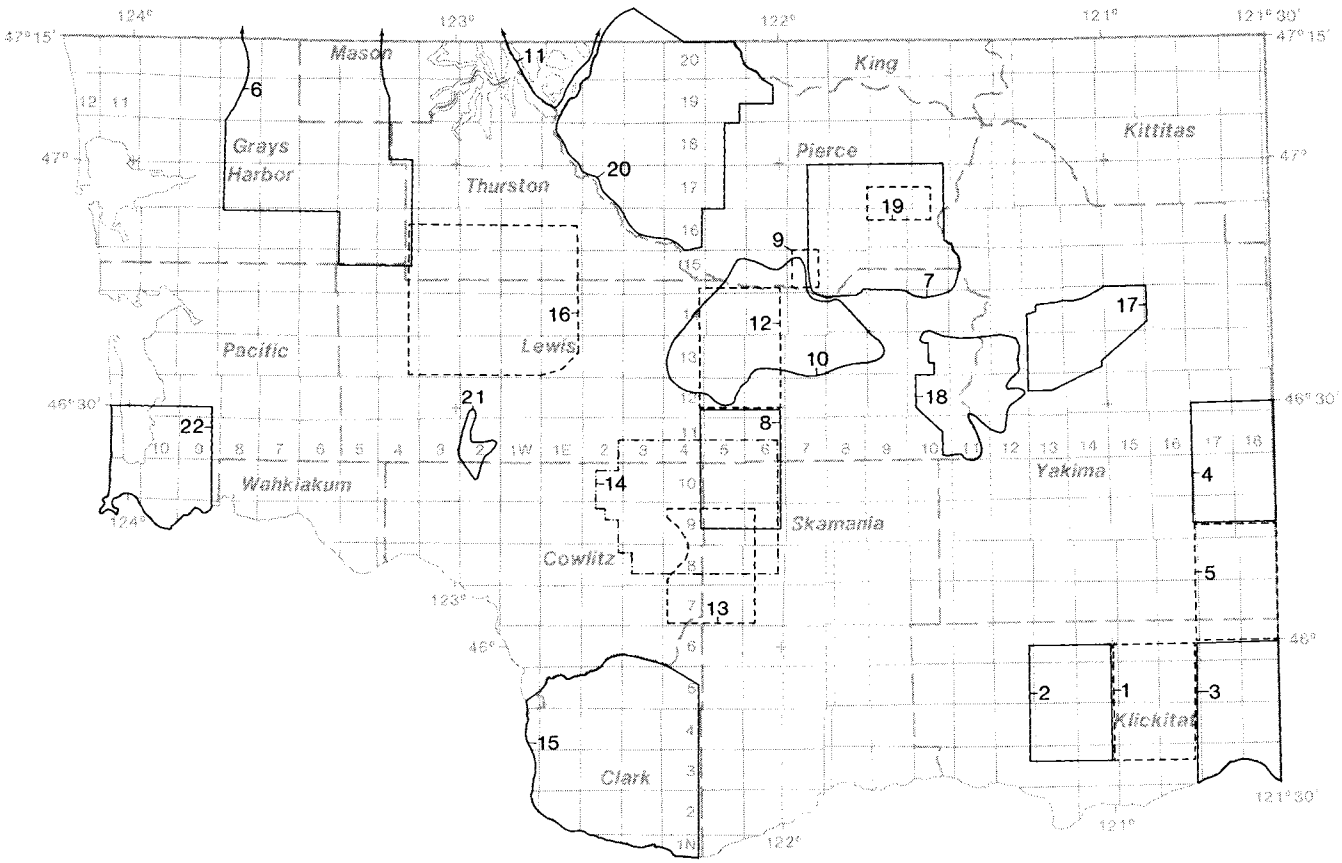

Figure 3.-Index to sources of map data, scales 1:31,680 through 1:60,500.

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

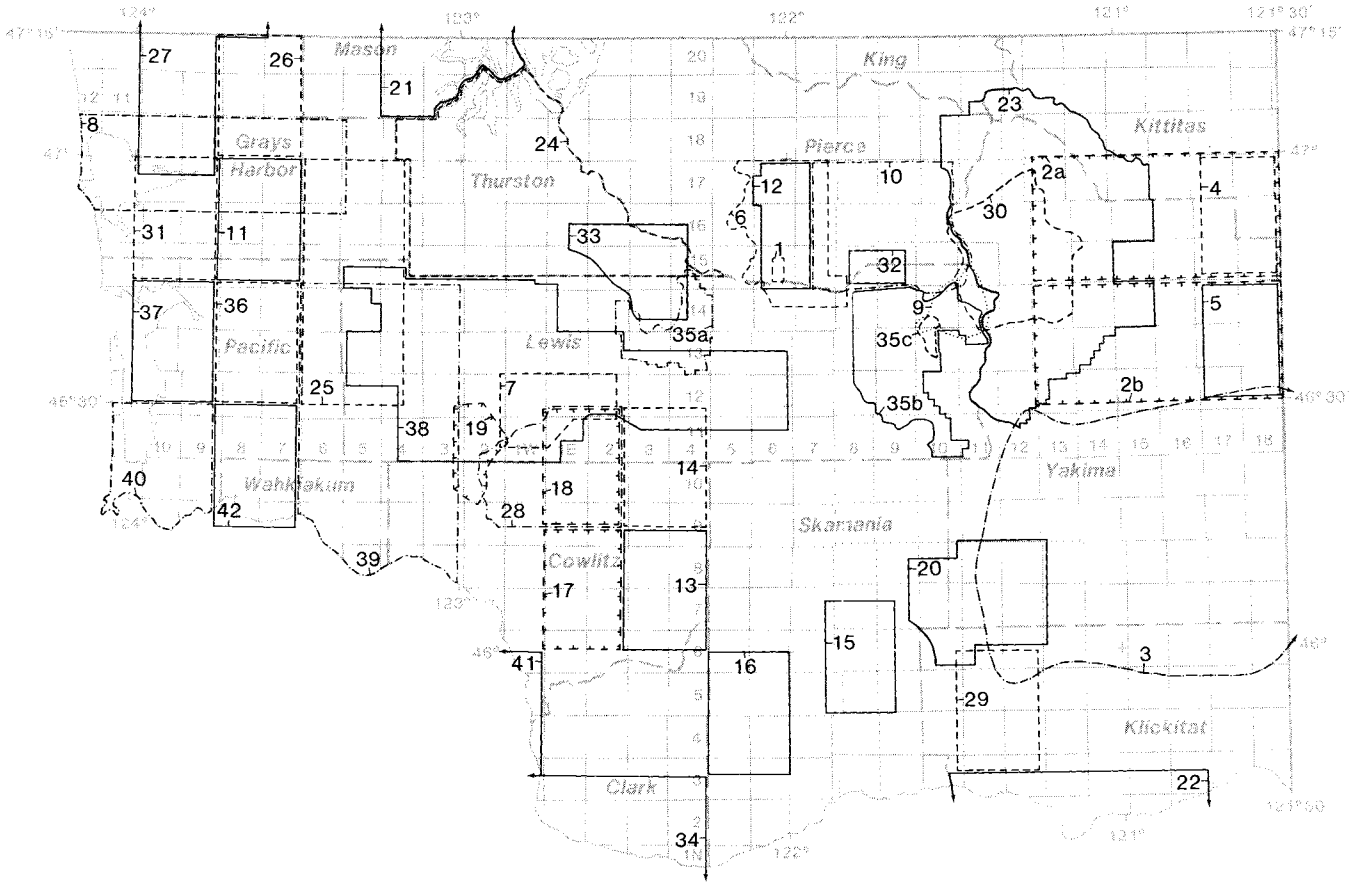

Figure 4-Index to sources of map data, scales 1:62,500 through 1:90,000.

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

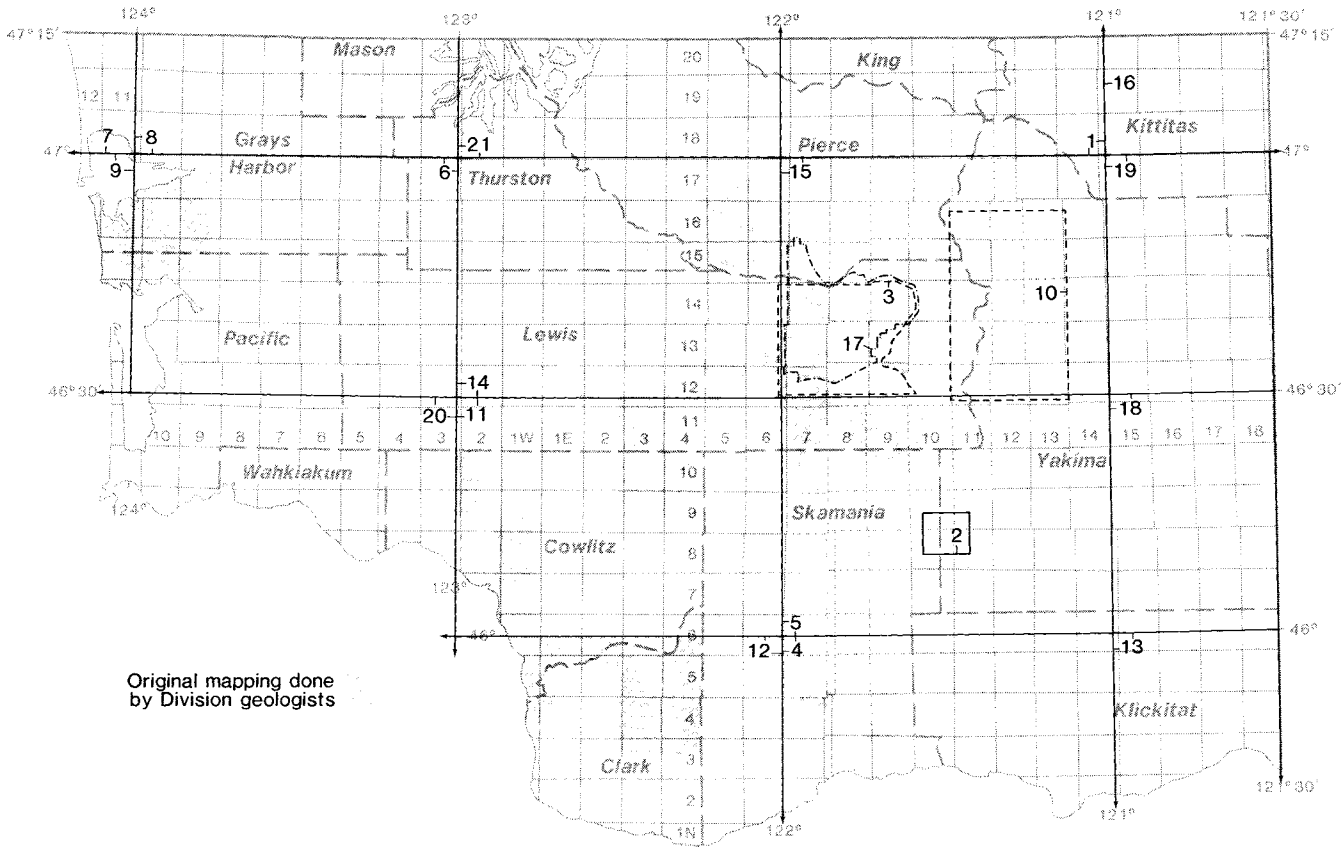

Figure 5-Index to sources of map data, scale 1:100,000.

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

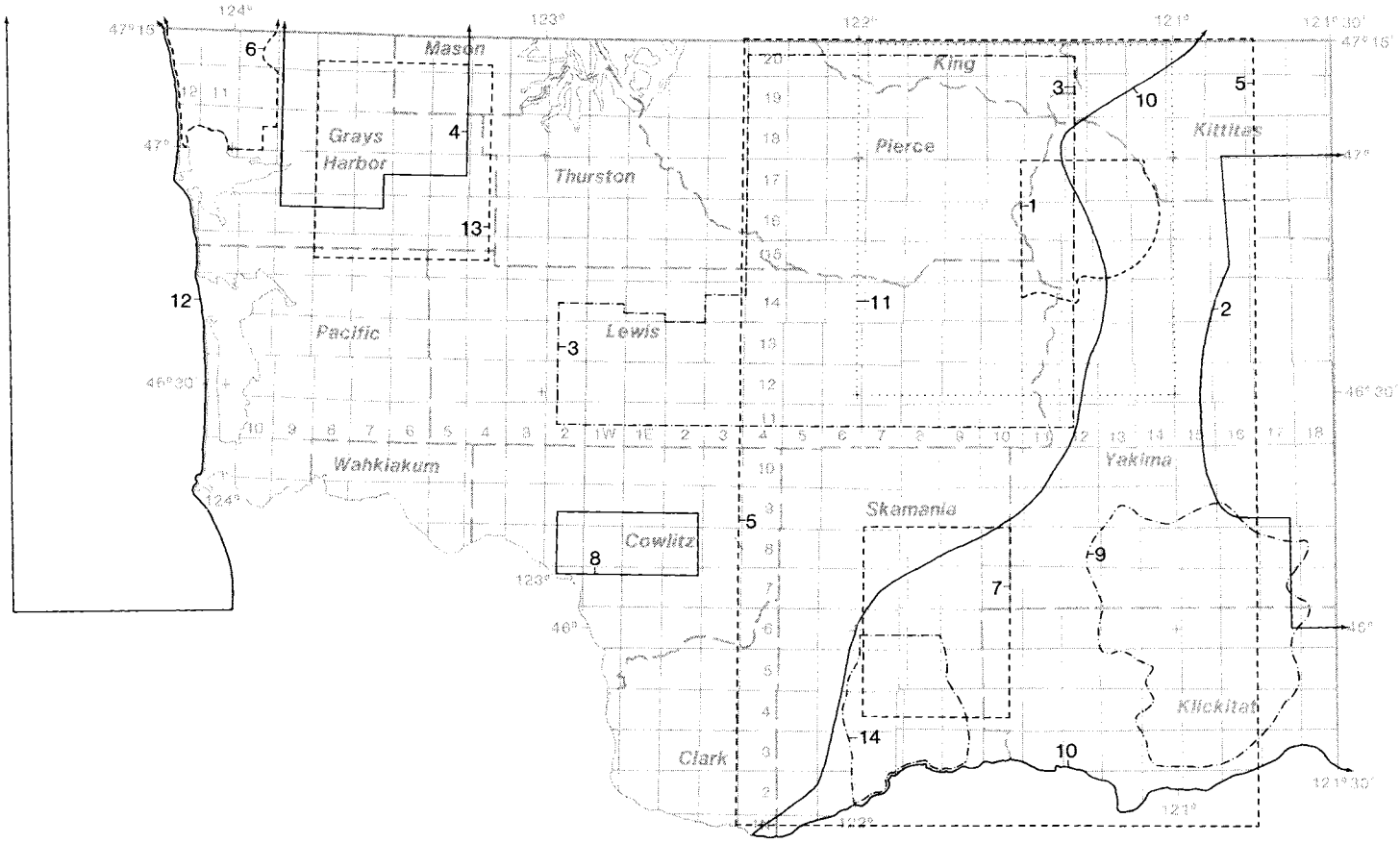

Figure 6–Index to sources of map data, scales 1:125,000 through 1:540,000.

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. Helens 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).

QPLc 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 ± 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 ± 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).

QPida — 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 ± 10,000 yr b.p. (Polivka, 1984). Upper age range based on radiocarbon date of 8,000 ± 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).

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

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

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

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

Rvt — Age uncertain. Position on diagram based on correlation with unit Rvr.

Rvd — Age range from Clayton (1983) and Schreiber (1981).

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

Rvb — 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 Rvr. 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 Ec_2) 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.

QPlian — 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).

Plida — Age range from Swanson and Clayton (1983).

Plian — 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).

Qc — 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.

Piq 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).

Pida 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).

QPvb 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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Some of the references listed in the following section are unpublished manuscripts or maps. Copies of these references are on file in the library at the Division's Olympia office, where they are available for inspection. Some proprietary information was used and is not in Division files.

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ERRATA

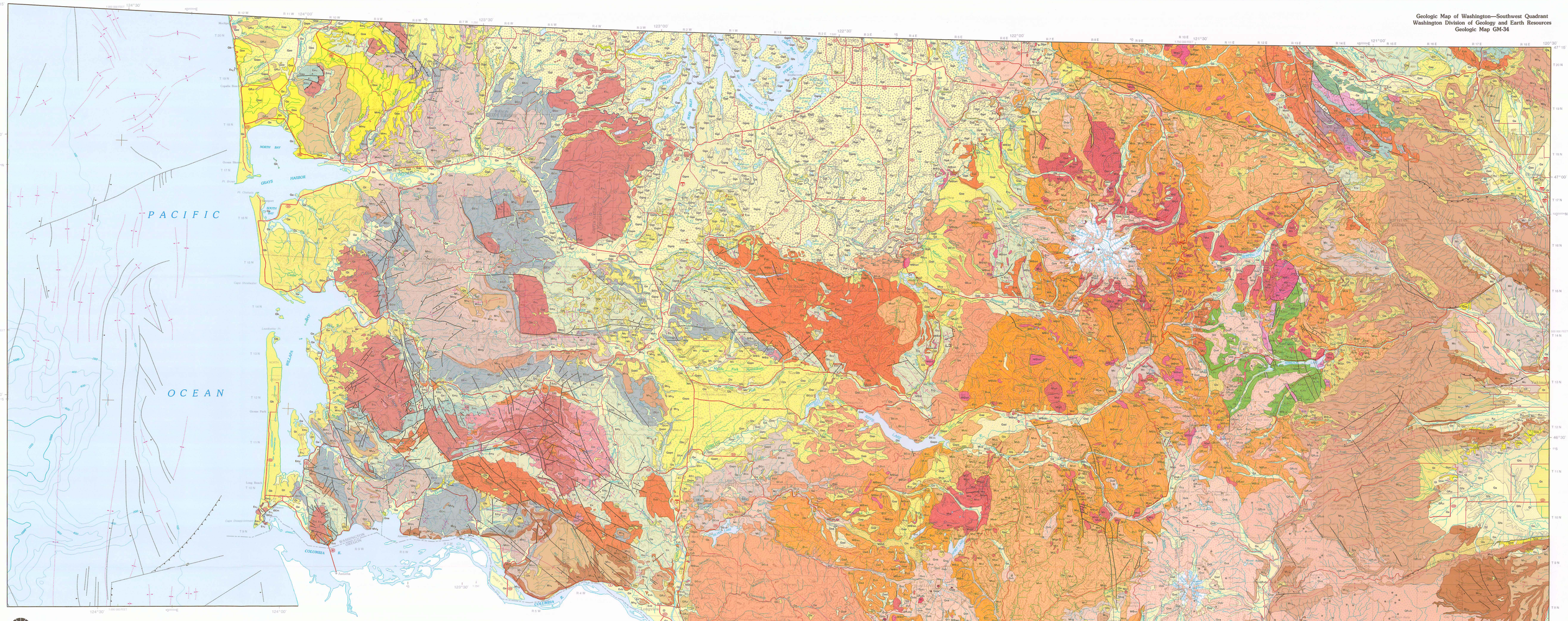
On the geologic map, Sheet 1:

The fault at the upper end of the North Fork Tieton River is shown as displacing Ꝑvr against Φvc; it should have shown Ꝑvr 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.



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Geologic Map GM-34
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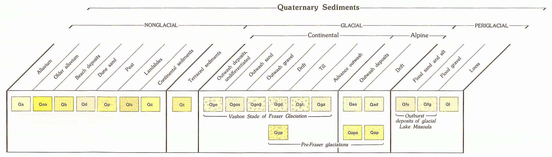
GEOLOGIC MAP OF WASHINGTON—SOUTHWEST QUADRANT

by

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

1987

Key To Geologic Units*


Quaternary Sediments
NONGLACIAL
GLACIAL
PERIGLACIAL
Continental
Alpine
Alluvium
Older alluvium
Beach deposits
Dune sand
Peat
Landslides
Colluvium
Terrace deposits
Osborne Bluff Member
Olympia Member
Vashon Stade of Fraser Glaciation
Olympia Member
Outwash gravel
Till
Advance outwash
Outwash deposits
Till
Peat and silt
Peat gravel
Lake
Qvgo
Qvgm
Qvgs
Qvgd
Qvgt
Qvgl
Qvgo
Qvgo
Qvgo

DESCRIPTIONS OF MAP UNITS

SEDIMENTS AND SEDIMENTARY ROCKS

QUATERNARY SEDIMENTS

Nonglacial

Qa **Alluvium**—Silt, sand, and gravel deposited in streambeds and fans; surface relatively undissected

Qoa **Older alluvium**—Silt, sand, and gravel deposited in streambeds and fans; may form low terraces; surface commonly dissected; commonly iron-oxide stained and, east of the Cascade Range, commonly contains caliche layers. Includes Skokomish Gravel

Qb **Beach deposits**—Fine to coarse sand forming beaches and associated active and stabilized back-beach dune fields, and minor estuarine deposits

Qd **Holocene dune sand**—Eolian sand and silt forming active dunes; dominant source is beaches along the Columbia River

Qp **Peat deposits**—Peat, muck, and lacustrine silt and clay rich in organic matter; deposited mostly in closed depressions

Qls **Landslide debris**—Clay, silt, sand, gravel, and larger blocks; unstratified and poorly sorted; surface commonly hummocky. Includes the 1980 debris avalanche of Mount St. Helens (Lipman and Mullineaux, 1981), talus, and all other mass-wasting deposits

Qc **Pleistocene continental sediments**—Stratified clay, silt, sand, gravel, and peat of lacustrine, estuarine, and fluvial origin; near Mount Rainier contains deposits of volcanic mudflows. Includes Kitsap, Alderton, and Puyallup Formations, and the Damon silt (Moore, 1965)

Periglacial

Loess

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

Upper Pleistocene Outburst Deposits of Glacial Lake Missoula

Qfs **Flood sand and silt**—Silt, sand, and clay, commonly grading into unit Qfg; contains slackwater deposits and cross-bedded fine-grained surge deposits, and some interbedded gravels

Qfg **Flood gravel**—Boulder to cobble gravel with sandy matrix and minor silt interbeds; generally crossbedded with foreset beds dipping downvalley

Terraced Sediments

Qt **Terraced sediments**—Silt, sand, and gravel of diverse compositions and origins, such as proglacial outwash, glacial outburst deposits, older alluvium, lahars, and uplifted coastal marine and estuarine deposits. Includes parts of the Lakedale and Kittitas Drifts

Glacial

Deposits of Continental Glaciers—Puget Lobe of the Cordilleran Ice Sheet

Vashon Stade of the Upper Pleistocene Fraser Glaciation

Qgd **Undifferentiated glacial drift**—Clay, silt, sand, and gravel; contains moraines and mixtures of till and outwash not separately mappable. Consists of part of the Vashon Drift

Qga **Advance outwash**—Outwash sand and gravel and lacustrine clay, silt, and sand deposited during advance of glaciers; sands commonly thick, well sorted and fine grained, with lenses of coarser sand and gravel; locally contains nonglacial sediments. Consists of Colvos Sand and part of the Vashon Drift

Qgt **Till**—Unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and boulders deposited directly by glacial ice; locally contains outwash sand and gravel both within and overlying till. Consists of part of the Vashon Drift

Qgo **Undifferentiated outwash deposits**—Recessional and proglacial stratified sand and gravel; locally contains silt and clay. Consists of part of the Vashon drift

Qgos **Outwash sand**—Recessional and proglacial stratified sand; locally contains silt, clay, and gravel. Consists of part of the Vashon Drift

Qgog **Outwash gravel**—Recessional and proglacial, stratified pebble, cobble, and boulder gravel deposited in meltwater streams and their deltas; locally contains ice-contact deposits. Includes Steilacoom Gravel and part of the Vashon Drift

Pre-Fraser Glacial Deposits

Qgp **Undifferentiated drift**—Till and outwash sand and gravel; commonly oxidized. Includes Salmon Springs, Orting, and Stuck Drifts, and Helm Creek drift of Carson (1970)

Deposits of Alpine Glaciers

Fraser Glaciation and Younger Deposits

Qad **Undifferentiated drift**—Till and outwash sand and gravel. Includes Burroughs Mountain, Garda, and McNeely Drifts, parts of Evans Creek and Lakedale Drifts, and McDonald Ridge drift (Hopkins, 1976)

Qao **Outwash deposits**—Stratified sand and gravel; locally contains silt and clay. Includes parts of Evans Creek and Lakedale Drifts and Chow Chow drift (Moore, 1965)

Pre-Fraser Glacial Deposits

Qap **Undifferentiated drift**—Till and outwash sand and gravel. Includes Lookout Mountain Ranch Drift, parts of Wingate Hill, Hayden Creek, and Kittitas Drifts, White Salmon drift (Hopkins, 1976), Mobray drift (Carson, 1970), and parts of the Humptulips drift (Moore, 1965) and Amboy drift (Mundorff, 1964, 1984)

Qapo **Outwash deposits**—Outwash sand and gravel with minor silt and clay. Includes Logan Hill Formation, part of Hayden Creek, Kittitas, and Wingate Hill Drifts, part of the Humptulips drift (Moore, 1965), part of the Amboy drift (Mundorff, 1964, 1984), and the Weatherwax and Wedekind Creek formations (Carson, 1970)

PLEISTOCENE-PLIOCENE SEDIMENTS

Continental

QPc **Continental sediments**—Gravel, sand, silt, and clay; deposits of the ancestral Columbia River contain distinctive orange quartzite clasts thought to be derived from northeast Washington; in the southern foothills of the Olympic mountains, moderately to intensely deformed alluvial sand and gravel; at Swale Creek valley, consists of material eroded from adjacent basaltic terrane and is overlain by loess. Includes the Troutdale Formation, and the Swale Creek valley sedimentary deposits (Newcomb, 1969)

PLIOCENE SEDIMENTS

Continental

Pc **Continental sediments**—Weakly cemented, moderately sorted cobble to pebble gravel with thin sand, silt, clay, and tephra interbeds; deposited by ancestral Yakima River and by smaller streams mainly in the Columbia Basin. Includes Thorp Gravel

MIOCENE SEDIMENTARY ROCKS

Marine

Mm$_2$ **Middle to upper Miocene marine sedimentary rocks**—Coarse- to fine-grained, silty, friable lithofeldspathic and feldspatholithic sandstone, locally dominated by conglomerate, siltstone, and mudstone; blue-gray when fresh, orange-brown when weathered; locally tuffaceous; most commonly massive, but bedding locally enhanced by conglomerate lenses and beds, carbonized wood, mica flakes, and concretionary beds; mudstone and siltstone beds are common. Contains foraminiferal faunas referable to the Mohnian and Delmontian Stages. Consists of Montesano Formation

Mm$_1$ **Lower to middle Miocene marine sedimentary rocks**—Fine-grained, silty feldspathic sandstone; friable, micaceous, gray when fresh, weathers to olive brown or creamy orange; massive to thin bedded; locally tuffaceous; abundant siltstone that contains macerated carbonaceous material; local basaltic sandstone, pebble conglomerate, and poorly sorted basal conglomerate. Contains foraminiferal faunas referable to the Saucesian, Relizian, and Luisian (?) Stages. Consists of the Astoria Formation

Continental

Mc **Continental sedimentary rocks**—Poorly consolidated to semiconsolidated sandstone, siltstone, and conglomerate, commonly tuffaceous; includes some tuff breccias, lahars, volcanic arenites, and peat; primarily the products of fluvial systems draining Tertiary volcanic terranes. Includes Mashel, Wilkes, and Dalles Formations and part of the Ellensburg Formation

Mcg **Continental sedimentary rocks, conglomerate**—Conglomerate with abundant dark-colored porphyritic andesite clasts, debris flow breccia, pebbly volcaniclastic sandstone, siltstone, and minor airfall tuff; commonly thick bedded. Consists of Eagle Creek Formation

OLIGOCENE-EOCENE SEDIMENTARY ROCKS

Marine

ƟEm **Oligocene to upper Eocene marine sedimentary rocks**—Indistinctly bedded to massive, commonly concretionary, light-gray tuffaceous siltstone and fine-grained tuffaceous sandstone; lower strata contain discontinuous beds of basaltic and glauconitic sandstone; dominantly offshore marine but grades into nonmarine volcaniclastic rocks east of Chehalis. Contains foraminiferal faunas referable to the Refugian and Zemmorian Stages. Consists of the Lincoln Creek Formation and part of Unit B of Wolfe and McKee (1972)

Nearshore

ƟEn **Oligocene to upper Eocene nearshore sedimentary rocks**—Basaltic conglomerate, sandstone, tuffaceous siltstone, pumice-lithic lapilli tuff, claystone, and lignite; locally interbedded with basaltic andesite flows; depositional environments range from nearshore marine to nonmarine; contains foraminiferal fauna referable to the Refugian Stage. Consists of the Toutle Formation

EOCENE SEDIMENTARY ROCKS

Marine

Em$_2$ **Middle to upper Eocene marine sedimentary rocks**—Laminated to massive, tuffaceous siltstone, claystone, shale, and massive to crossbedded micaceous feldspathic sandstone in lower part, interbeds of basaltic sandstone; locally interbedded with basalt flows, tuffs, tuff breccias, and conglomerates. Contains foraminiferal faunas referable to the Narizian Stage. Includes part of the McIntosh Formation, Stillwater Creek Member of the Cowlitz Formation (Henriksen, 1956), Humptulips Formation (Rau, 1984, 1986), siltstone of Skamokawa Creek (Wells, 1981), siltstone of Cliff Point (Wells, 1979), siltstone and sandstone at Omeara Point (Wells, in press), siltstone at Shoalwater Bay (Wells, in press), and part of Unit B of Wolfe and McKee (1972)

Em$_1$ **Lower? to middle Eocene marine sedimentary rocks**—Siltstone and massive to planar-laminated micaceous feldspathic sandstone, locally with graded bedding. Contains foraminiferal faunas referable to the Ulatisian Stage. Includes Unit A of Wolfe and McKee (1972), part of the McIntosh Formation (Wagner, 1967a), sandstone of Megler (Wells, 1979), part of the Crescent Formation (Rau, 1966), and the Hoh Assemblage (Rau, 1986)

Nearshore

En **Middle to upper Eocene nearshore sedimentary rocks**—Nearshore marine to nonmarine micaceous feldspathic sandstone, siltstone, shale, carbonaceous siltstone, claystone, and thick coal seams; locally interbedded with basalt flows and volcaniclastic rocks. Contains foraminiferal faunas referable to the Narizian Stage. Includes Skookumchuck Formation, Olequa Creek Member of the Cowlitz Formation (Henriksen, 1956), Cowlitz Formation (Wells, 1981), and rocks mapped as upper McIntosh by Pease and Hoover (1957) [See Logan, 1987a]

Continental

Ec$_2$ **Middle to upper Eocene continental sedimentary rocks**—Micaceous feldspathic sandstone and lithofeldspathic sandstone interbedded with siltstone, shale, claystone, and coal; locally, interbedded with lava flows, tuffs, volcaniclastic breccias, and pebble conglomerates, and brackish-water deposits. Includes Puget Group undivided, Carbonado, Spiketon, and Roslyn Formations, parts of the Naches Formation, the Summit Creek sandstone (Ellingson, 1959), the Lookout Creek sandstone (Schreiber, 1981) and the beds of Chambers Creek (Winters, 1984)

Ec$_1$ **Lower to middle Eocene continental sedimentary rocks**—Micaceous feldspathic sandstone and lithofeldspathic sandstone with lesser amounts of carbonaceous siltstone and shale, pebbly sandstone, conglomerate, and coal; locally interbedded with tuffs and volcaniclastic breccias. Consists of Swauk and Manastash Formations

CRETACEOUS AND JURASSIC SEDIMENTARY ROCKS

Marine

KJm **Marine sedimentary rocks**—Lithofeldspathic sandstone and mudstone, with lesser conglomerate and greenstone, minor chert, and very rare green tuff. Radiolarian faunas indicate an age of Triassic(?), Jurassic, and Early Cretaceous; limestone clasts in a conglomerate have yielded fusulinids of probable Permian age. Consists of part of the Russell Ranch Formation

KJmct **Chert-rich marine sedimentary rocks**—Lithofeldspathic sandstone, mudstone, radiolarian chert, greenstone, green tuff, and red shale; characterized by thin stringers of altered green tuff and red shale within chert-rich horizons; contains radiolarian fauna referable to the Tithonian and Valanginian or Hauterivian Stages. Consists of part of the Russell Ranch Formation

METAMORPHIC ROCKS

JURASSIC METAMORPHIC ROCKS

Jsh **Schist**—Very fine grained albite-epidote-chlorite greenschist and blueschist with minor intercalations of ironstone and ferruginous quartzite in the greenschist; commonly highly foliated and well recrystallized, but locally, relict textures suggest derivation from porphyritic volcanic rocks, tuffs, and rare mafic intrusive rocks; locally interbedded with phyllite. Probable Late Jurassic protolith age and Early Cretaceous metamorphic age. Includes parts of the Easton Schist

Jph **Phyllite**—Very fine grained, black to gray, graphitic chlorite-sericite-quartz phyllite; commonly highly crinkled; locally interbedded with greenschist and blueschist. Probable Late Jurassic protolith age and Early Cretaceous metamorphic age. Consists of parts of the Easton Schist

Jog **Orthogneiss**—Well foliated, metaplutonic rocks of intermediate composition, primarily quartz diorite gneiss, with minor local amphibolite at Indian Creek. Consists of the tonalite gneiss of Hicks Butte (Frizzell and others, 1984) and parts of the Indian Creek complex (Miller, 1985)

PRE-JURASSIC METAMORPHIC ROCKS

pJsc **Schist**—Very fine grained graphitic garnet biotite schist, locally with staurolite, andalusite, and rare cordierite; relict bedding common; intruded by a quartz diorite that has an age of about 157 m.y. (Frizzell and others, 1984); contains unmapped bodies of metatonalite and gabbro. Consists of the Lookout Mountain Formation

pJam **Amphibolite**—Very fine grained schistose epidote amphibolite with minor mica schist, metadiorite, metagabbro, and cataclastic hornblende tonalite gneiss

VOLCANIC ROCKS AND DEPOSITS

QUATERNARY VOLCANIC ROCKS AND DEPOSITS

Lava Flows

Qvd **Pleistocene dacite flows**—Porphyritic dacite; northwest of Mount Adams, two-pyroxene, glassy intracanyon flow; at Spiral Butte, very fine grained, light-gray, platy, flow-banded hypersthene-hornblende dacite flows; along Clear Fork of the upper Cowlitz River, very fine grained quartz-hornblende-hypersthene dacite intracanyon flow

Qva **Andesite flows**—Porphyritic to aphyric, hypersthene-augite andesite, olivine-pyroxene andesite, and hornblende andesite with minor dacite; blocky to platy flows, commonly vesicular, commonly with breccia bases; form the stratovolcanoes at Mount Rainier, Mount Adams, and Mount St. Helens, voluminous valley-filling flows, monogenetic volcanic piles, plug domes; lesser amounts of basaltic andesite associated with basaltic volcanic fields (unit Qvb). Includes the Tieton Andesite and andesite flows of Mount Rainier (Fiske and others, 1963), Mount Adams (Hammond, 1980; Hildreth and others, 1983), and Mount St. Helens (Hopson, 1980)

Qvb **Basalt flows**—Light-gray to black, microphyric to coarsely phyric olivine basalt and olivine-clinopyroxene basalt; forms aa flows and pahoehoe flows with lava tubes, vent areas typically marked by cinder and scoria cones and accumulations of tephra and bombs; flows form volcanic fields at Indian Heaven, King Mountain, Tumac Mountain, Marble Mountain, and Soda Peaks. Includes Cave Basalt and other basalt flows at Mount St. Helens (Hopson, 1980)

Volcaniclastic Deposits

Qvc **Volcaniclastic deposits, undivided**—Ash- to block-sized lithic and pumice-rich pyroclastic deposits, debris flows, laharic deposits, pumice lapilli, and ash tephra, and fluvial gravels, sand, and silt; deposited by pyroclastic flows, lahars, and debris avalanches on or near Quaternary stratovolcanoes; at Mount St. Helens, lithic clasts consist of gray to pink hornblende-hypersthene dacite and andesite and lesser black andesite and basalt, locally interbedded with glacial till (Hopson, 1980); at Mount Adams, primarily andesitic debris

Qvp **Holocene pyroclastic flows**—Dacitic to andesitic, pumiceous pyroclastic-flow deposits of 1980 Mount St. Helens eruptions (Lipman and Mullineaux, 1981); mostly poorly sorted, ash-sized, crudely graded deposits of glass shards, pumice, broken phenocrysts, and lithic fragments and lesser lapilli- to block-sized pumice and lithic fragments

Qvl **Lahars**—Unsorted to poorly sorted, generally unstratified mixtures of cobbles and boulders supported by a matrix of sand or mud; also contains lesser stratified fluvial deposits; primarily late Pleistocene to Holocene deposits originating on Quaternary stratovolcanoes. Includes Osceola and Electron Mudflows, the Lily Creek Formation, the Greenwater lahar (Crandell, 1971), Paradise debris flow (Crandell, 1969), Trout Lake mudflow (Hopkins, 1976), lahars from 1980 Mount St. Helens eruptions (Lipman and Mullineaux, 1981) in the Toutle River, Muddy River, and Pine Creek drainages and pre-1980 Mount St. Helens lahars (Scott, 1986)

PLEISTOCENE-PLIOCENE VOLCANIC ROCKS

Lava Flows

QPvd **Dacite flows**—Light-gray to purplish-gray porphyritic oxyhornblende-pyroxene dacite; forms ridge-capping flows at Johnson Creek and Snyder Mountain and sheet flows east of the White Salmon River

QPva **Andesite flows**—Gray olivine-hypersthene andesite, pyroxene andesite, hornblende andesite, and hypersthene-hornblende andesite flows and associated breccias; erupted from vents in the Goat Rocks area, northwest of Mount Rainier, and in the Vancouver area. Includes andesite of Bee Flat (Fiske and others, 1963) and some flows of the Boring Lava

QPvb **Basalt flows**—Gray to gray-black, aphyric and plagioclase-olivine-phyric and pyroxene-olivine-phyric basalt; commonly trachytic; platy, blocky, and columnar jointed; commonly scoriaceous; erupted from multiple vents distinguished by cinder cones; at Hogback Mountain, olivine basalt and basaltic andesite form a shield volcano. Includes part of the Boring Lava, volcanic rocks of Simcoe Mountains (Sheppard 1967), mafic rocks of Hogback Mountain (Clayton, 1983), basalt porphyry of Balch Lake (Newcomb, 1969), and basalt of the Lincoln Plateau (Sheppard, 1967)

PLIOCENE VOLCANIC ROCKS

Lava Flows

Pvr **Rhyolite**—Flow-banded flows and domes, obsidian, breccias, lahars, and tuffs; at Devils Horns, tuffs are pumiceous and vitric. Includes Devils Horns rhyolite (Clayton, 1983) and volcanic rocks of Simcoe Mountains (Sheppard, 1960)

Pvd **Dacite flows**—Light- to medium-gray porphyritic dacite flows and flow breccia with phenocrysts of plagioclase, hornblende, quartz, and biotite; occurs as scattered remnants; also contains tuffs, lava domes, and hypabyssal intrusions

Pvb **Basalt flows**—Olivine basalt, olivine-augite basalt, and basaltic andesite flows, agglomerates, pyroclastic rocks, and dikes; the pyroclastic rocks contain welded basaltic bombs, blocks, scoria, and spatter. Includes the Devils Washbasin basalt (Clayton, 1983) and the olivine basalt of Bethel Ridge (Swanson, 1978)

Volcaniclastic Rocks

Pvt **Tuff**—Poorly consolidated pyroclastic debris to welded, dacitic lithic-crystal-vitric tuff and tuff breccia; crystals are augite and plagioclase. Includes the tuff at Midway (Hammond, 1980)

MIOCENE VOLCANIC ROCKS

Lava Flows

Mvd **Dacite flows**—Porphyritic dacite flows and flow breccia; northeast of Mount St. Helens white to light-greenish-gray, plagioclase- and pyroxene-phyric, rarely with biotite and hornblende; forms flow-dome complexes and persists as scattered flow remnants; south of the Cispus River, black, glassy, plagioclase-augite-phyric, columnar flows and flow breccia

Mva **Andesite flows**—Pyroxene andesite and two-pyroxene andesite and basaltic andesite flows and flow breccia; also contains minor hornblende-pyroxene andesite and clinopyroxene basalt flows interbedded with volcaniclastic breccia, tuff, and volcanic sandstone; lavas commonly porphyritic; shield volcanoes of this unit are recognized at Fifes Peak, Cliffdell, and south of Bethel Ridge. Includes the Fifes Peak Formation, part of the volcanic rocks of Eagle Gorge (Frizzell and others, 1984), lava flows of Council Bluff (Hammond, 1980), lava flows of Three Corner Rock (Hammond, 1980), and Stevenson Ridge lavas (Berri and Korosec, 1983)

Mvb **Basalt flows**—Black to medium-gray and green, aphyric to sparsely plagioclase-, olivine-, and augite-phyric basalt flows and flow breccia, with minor interbedded mafic tuff, laharic breccia, and volcanic sedimentary rock

Volcaniclastic Rocks

Mvr **Rhyolite**—Gray to white, banded, devitrified rhyolite interpreted as rheoignimbrite, with rare black welded vitrophyre and local basal unwelded pumice-perlite tuff; interbedded with rare rhyolitic sandstone, siltstone, and coal. Includes White River rheoignimbrite (Fischer, 1970)

Mvc **Volcaniclastic rocks**—Massive to well-bedded volcaniclastic breccias and conglomerates, tuffs, tuff breccias, and volcanic sandstones and siltstones; northeast of Mount St. Helens, andesitic to rhyolitic, pumice-lithic tuff and tuff breccia, volcanic siltstone, sandstone, conglomerate, and minor coal beds, locally associated with plugs and flows of dacite and rhyolite; south and west of Naches Pass, well-bedded andesitic breccia, tuff, and volcanic sandstone with rare white pumice tuff locally containing graded beds; west of Randle, poorly sorted, massive breccia and conglomerate that has sand- to boulder-sized clasts of augite andesite; near Burnett in Pierce County, poorly sorted, unstratified, matrix-supported breccia and conglomerate that has clasts of andesite and hornblende dacite, and cross- bedded, pumiceous sandstone, lapillistone, and thin tuff; in the Kittitas Valley, mostly volcaniclastic sandstone and siltstone, and minor conglomerate and feldspathic sandstone interbedded with or stratigraphically above flows of Grande Ronde Basalt (unit Mv$_g$). Includes the Randle laharic breccia-conglomerate (Fisher, 1960) and, east of the Cascades, part of the Ellensburg Formation

Mvt **Tuff**—Welded to nonwelded, vitric to crystalline, lithic and pumiceous dacite and rhyolite tuffs and tuff breccias; commonly quartz phyric; contains pyroclastic flows and airfall tuff with minor silicic lava flows and volcaniclastic sedimentary rocks. Includes part of the volcanic rocks of Eagle Gorge (Frizzell and others, 1984), welded tuff of The Palisades (Fiske and others, 1963), and Stevens Ridge Formation north of Mount Rainier

Flows of Miocene Columbia River Basalt Group

Yakima Basalt Subgroup

(Erupted from fissure vents in southeast Washington and adjacent Oregon and Idaho)

Mv$_s$ **Middle to upper Miocene Saddle Mountains Basalt**—Fine-grained, sparsely phyric tholeiitic and olivine flood basalt; generally 5 to 35 m thick; as much as 100 m thick west of Kelso; forms sheet flows and intracanyon flows, with sedimentary interbeds of tuffaceous sandstone, siltstone, and pumiceous conglomerate. K-Ar ages for flows shown range from approximately 13.5 to 10.5 m.y.; contains Umatilla, Wilbur Creek, Asotin, Pomona, and Elephant Mountain Members in the Columbia Basin; west of the Cascade Mountains, consists only of Pomona Member, which includes flows mapped as basalt of Pack Sack Lookout (Snavely and others, 1973; Magill and others, 1982)

Mvi$_s$ **Middle Miocene Saddle Mountains Basalt, invasive flows**—Sills and dikes of olivine basalt and peperites thought to be formed by the invasion of the Pomona Member of the Saddle Mountains Basalt (Mv$_s$) into poorly consolidated sediments. Consists of basalt mapped as intrusive basalt of Pack Sack Lookout (Snavely and others, 1973)

Mv$_w$ **Middle Miocene Wanapum Basalt**—Fine- to coarse-grained, sparsely phyric to abundantly phyric tholeiitic basalts, forming sheet flows that have thin sedimentary interbeds and a few intracanyon flows. K-Ar ages range from approximately 15.6 to 14.5 m.y.; contains Frenchman Springs, Roza, and Priest Rapids Members in the Columbia Basin; west of the Cascade Mountains, consists only of Frenchman Springs Member; includes flows mapped as Cape Foulweather Basalt

Mv$_g$ **Middle Miocene Grande Ronde Basalt**—Fine-grained, aphyric to very sparsely phyric flood basalt with basaltic andesite chemistry, forms broad sheet flows with sedimentary interbeds of tuffaceous sandstone, siltstone, and conglomerate. K-Ar ages for basalt range from approximately 16.5 to 15.6 m.y. Consists of magnetostratigraphic units R_1, N_1, R_2, and N_2 (Swanson and others, 1979b) in the Columbia Gorge and eastern Washington; west of the Cascade Mountains probably contains only R_2 and N_2; includes flows mapped as Depoe Bay Basalt

Mvi$_g$ **Middle Miocene Grande Ronde Basalt, invasive flows**—Sills and dikes of basaltic andesite and peperites thought to be formed by the invasion of Grande Ronde Basalt (Mv$_g$) into poorly consolidated sediments. Consists of basalt mapped as intrusive Depoe Bay Basalt

MIOCENE-OLIGOCENE VOLCANIC ROCKS

Undivided

MƟv **Volcanic rocks**—Undifferentiated volcanic rocks of uncertain age, probably early Oligocene through early Miocene

Lava Flows

MƟva **Andesite flows**—Porphyritic pyroxene andesite flows and flow breccia and lesser interbedded volcaniclastic rock

Volcaniclastic Rocks

MƟvc **Volcaniclastic rocks**—Massive to well-bedded breccias, conglomerates, tuffs, tuff breccias, and volcanic sandstones produced by debris flows, mudflows, pyroclastic flows, and fluvial reworking of volcanic deposits. Includes rocks mapped earlier as Ohanapecosh Formation by Wise (1970), but now known to be mostly younger than the Ohanapecosh Formation

MƟvt **Tuff**—Welded to nonwelded, vitric to crystalline, lithic to pumiceous dacite tuffs and tuff breccias; commonly quartz phyric; products of pyroclastic flows and air fall; contains minor silicic lava flows and volcanic sedimentary rocks. Includes Stevens Ridge Formation south of Mount Rainier, Bumping River tuff (Hammond, 1980), Rattlesnake Creek tuff (Schreiber, 1981), and the tuff of Burnt Mountain (Swanson, 1978)

OLIGOCENE VOLCANIC ROCKS

Lava Flows

Ɵvr **Rhyolite flows**—Light-buff rhyolite east of Mount Rainier, forming an 80-m-thick, 4-km-long lens within the upper Ohanapecosh Formation (unit Ɵvc); has contorted flow banding and spherulites; contains a flow-banded plug at South Cowlitz Chimney east of Mount Rainier

Ɵvd **Dacite flows**—Massive to flow-banded, aphyric to porphyritic, dacite and minor rhyolite flows, flow breccia, domes, and plugs; phenocrysts consist of euhedral quartz, plagioclase altered to microcrystalline quartz and feldspar, and altered mafic minerals; interbedded with silicic lapilli tuff

Ɵva **Andesite flows**—Aphyric to porphyritic andesite flows and flow breccia; in the Toutle Mountain Range, platy porphyritic two-pyroxene andesite interbedded with pumice-lithic tuff, volcaniclastic sandstone, conglomerate, and minor dacite and basalt flows; in the Mount Rainier area, porphyritic pyroxene andesite interbedded with lithic lapilli tuff and locally thick volcaniclastic breccia and conglomerate; in southwest Skamania County, thick flows of clinopyroxene basaltic andesite. Includes part of the Ohanapecosh Formation and the Skamania volcanic rocks (Trimble, 1963)

Ɵvb **Basalt flows**—Aphyric to porphyritic pyroxene and olivine-pyroxene basalt and basaltic andesite flows, and flow breccia; interbedded with mafic tuff and volcaniclastic breccia hornfelsed in the contact aureole of the Spirit Lake pluton. Includes olivine basalt of Milk Creek (Swanson, 1978)

Volcaniclastic Rocks

Ɵvc **Volcaniclastic rocks**—Greenish to brown and maroon, andesitic to basaltic lithic breccia, tuff, and tuff breccia, and volcanic siltstone, sandstone, and conglomerate; interbedded with basalt and andesite flows and rare dacite to rhyolite flows and tuffs; breccias typically unstratified, crudely graded, or very thickly bedded, poorly sorted, with clasts of pyroclastic rock, porphyritic basaltic andesite to dacite, and aphyric to glassy lava, in a matrix of altered plagioclase, devitrified glass shards and clay; sandstone and ash to lapilli tuff commonly form well-bedded, graded, parallel-laminated, poorly to well-sorted sequences; fossil leaf impressions common in siltstone; at Wildcat Creek, contains vertebrate fossils; unit is commonly altered to zeolites and clay. Includes part of the Ohanapecosh Formation, volcanic rocks of Huckleberry Mountain (Frizzell and others, 1984), tuffaceous rocks of Wildcat Creek (Swanson, 1978), and sandstone of Spencer Creek (Swanson, 1978)

Ɵvt **Tuff**—Crystal-lithic and pumice-lithic tuff and tuff breccia; in the Mount St. Helens area, dominantly pyroxene- and plagioclase-phyric with lesser quartz-phyric, block to lapilli tuffs, commonly unstratified and poorly sorted; interbedded with volcanic sedimentary rocks and dacitic to andesitic flows or plugs; in the Rimrock Lake area, consists of red and violet tuff and tuffaceous sandstone and siltstone thoroughly altered to clay and interbedded with olivine basalt. Includes the tuff of Milk Creek (Swanson, 1978)

OLIGOCENE-EOCENE VOLCANIC ROCKS

Lava Flows

ƟEva **Lower Oligocene to upper Eocene andesite flows**—Platy to massive, vesicular to dense, porphyritic basaltic andesite flows and flow breccia, with lesser andesite, basalt, and dacite; flows commonly have oxidized, wavy bases and thin interbeds of shale, tuff, or volcanic sandstone and conglomerate; forms complexes of numerous, thin, irregularly shaped flows of limited areal extent; most flows are plagioclase-clinopyroxene phyric; two-pyroxene or olivine-phyric flows also present; zeolites and calcite common in amygdules and fractures. Includes part of the Hatchet Mountain Formation, part of the Goble Volcanics (Wilkinson and others, 1946), and part of the Northcraft Formation (Hammond, 1980)

Volcaniclastic Rocks

ƟEvc **Lower Oligocene to upper Eocene volcaniclastic rocks**—Massive to well-bedded, lapilli and ash pumice-lithic tuff, volcanic sandstone, and poorly sorted, unstratified, matrix-supported conglomerate or breccia with abundant wood fragments; interbedded with thin basaltic andesite flows and, at base of unit, with feldspathic sandstone, shale, and coal. Includes part of the Hatchet Mountain Formation, part of the Goble Volcanics (Wilkinson and others, 1946), and part of the Northcraft Formation (Hammond, 1980)

ƟEvt **Oligocene to upper Eocene tuff**—Welded and nonwelded, moderately to highly altered tuffs and tuff breccias of dacitic(?) composition. Includes part of the Northcraft Formation (Hammond, 1980)

EOCENE VOLCANIC ROCKS

Undivided

Ev **Volcanic rocks, undivided**—Basalt, basaltic andesite, and rhyolite flows and volcaniclastic rocks, with interbeds of feldspathic sandstone, siltstone, and rare coal. Includes part of the Naches Formation

Lava Flows

Evr **Rhyolite flows**—Rhyolite flows, and tuffs and associated flow breccia; flows are banded and have platy jointing; tuffs are welded crystal-lithic ash flows containing some pumice lapilli and are interbedded with minor thin feldspathic sandstones and shales; contains associated plugs and dikes on Teanaway Ridge. Includes parts of the Naches Formation

Eva **Andesite flows**—Porphyritic and minor aphyric andesite flows and flow breccia; in the Centralia-Chehalis area, massive to platy clinopyroxene basaltic andesite with lesser basalt and andesite, interbedded with pyroclastic rocks and feldspathic sandstones, especially at the base; becomes olivine-bearing and more flow dominated eastward toward Morton; south of Cliffdell along the Naches River, altered green to brownish-green plagioclase-clinopyroxene andesite, rarely with hornblende, and lesser volcanic breccia and tuff; in the Taneum Ridge area, altered pyroxene andesite, dacite and rhyolite flows interbedded with commonly welded rhyolitic tuffs, volcaniclastic breccia, and minor coal-bearing sedimentary rock. Includes the Taneum Formation and part of the Northcraft Formation

Evb **Basalt flows**—Aphyric to sparsely phyric basalt flows and flow breccia; in the Willapa Hills, subaerial clinopyroxene-phyric basalt with minor pillow basalt, interbedded with subaqueous mafic tuff, volcaniclastic breccia, basaltic sandstone and conglomerate, and marine micaceous feldspathic sandstone and siltstone; in the Summit Creek area southeast of Mount Rainier, dense, sparsely phyric clinopyroxene basalt interbedded with silicic tuff, argillite, and feldspathic and volcaniclastic fluvial sandstone; on Teanaway Ridge, dense to glassy pyroxene and rare olivine basalt and basaltic andesite with mafic tuff and minor intermediate volcanic rocks, rhyolite tuffs, and feldspathic sandstone and siltstone; north of Manastash Ridge, microporphyritic olivine basalt with interbedded mafic tuff; north of the Little Naches River, altered aphyric to porphyritic pyroxene basalt, olivine-clinopyroxene basalt and pyroxene basaltic andesite, feldspathic sandstone and siltstone. Includes basalt of Summit Creek (Vance and others, in press), Teanaway Formation, basalt of Frost Mountain (Tabor and others, 1982), part of the Naches Formation, and volcanic rocks of Grays River [The Grays River unit includes rocks previously mapped as the Goble Volcanics Member of the Cowlitz Formation by Henriksen (1956), Goble Volcanics by Livingston (1966), volcanic rocks within the Cowlitz Formation by Livingston (1966), and volcanic rocks of Unit B by Wolfe and McKee (1972); see Phillips, 1987a, and Walsh, 1987a]

Volcaniclastic Rocks

Evc **Volcaniclastic rocks**—Andesitic volcaniclastic breccia, conglomerate, lithic tuff, volcanic sandstone, and siltstone; commonly interbedded with feldspathic sandstones and andesite flows; north of the Puyallup River, breccias and conglomerates of probable mudflow origin dominate; between the Puyallup and Nisqually Rivers and north of the Skookumchuck River, dominantly volcanic sandstones and siltstones, with lesser interbedded breccia and conglomerate. Includes part of the Northcraft Formation (Gard, 1968; Buckovic, 1974; Hagen, 1987)

Evt **Tuff**—Mafic and silicic tuff; in the Willapa Hills area, subaqueous, massive to well-bedded, palagonitic basaltic lapilli tuff and tuff breccia, basaltic sandstone, siltstone, and conglomerate; in the Cascade Range, the tuffs are silicic crystal lithic and pumiceous. Includes Pe Ell Volcanics Member of the Cowlitz Formation (Henriksen, 1956) and welded tuff at Spencer Creek (Swanson, 1964)

Crescent Formation Lava Flows and Volcaniclastic Rocks

Ev$_c$ **Lower to middle Eocene Crescent Formation**—Fine-grained, dominantly submarine tholeiitic basalt flows and flow breccia, typically with zeolitic or chloritic alteration; pillows and altered palagonite common; locally contains thin interbeds of basaltic tuff and siltstone with foraminiferal faunas referrable to the Ulatisian Stage; probably originated as mid-ocean ridge basalt and as seamounts; accreted to continent by middle Eocene time (about 48 m.y. ago); forms basement in the Coast Range

PRE-TERTIARY VOLCANIC ROCKS

Lava Flows

pTvr **Rhyolite**—Altered silicic volcanic rocks that have foliation well defined by aligned muscovite that wraps around relict quartz phenocrysts; locally deformed into sharp-hinged folds; originally may have been rhyolitic flows. May be part of the Russell Ranch Formation

CRETACEOUS-JURASSIC VOLCANIC ROCKS

Lava Flows

KJvb **Basalt flows**—Fault-bounded greenstone unit consisting of pillowed lavas and minor shale interbeds. May be part of the Russell Ranch Formation

KJmv **Metavolcanic rocks**—Tectonic blocks of pillowed greenstone in metasedimentary units of the Russell Ranch Formation; original mineralogy was augite and calcic plagioclase; metamorphosed to greenschist facies. Consists of part of the Russell Ranch Formation

INTRUSIVE ROCKS AND LAVA DOMES*

QUATERNARY INTRUSIVE ROCKS

Intermediate

Qida **Intrusive dacite**—Hornblende-hypersthene and hypersthene dacite, and andesite, forming Holocene domes on Mount St. Helens (Hopson, 1980) and Pleistocene domes at Butte Camp (Hopson, 1980), Tumtum Mountain (Mundorff and Eggers, in press), and near the headwaters of the Kalama River (Hopson, 1980)

Qian **Intrusive andesite**—Olivine andesite and light-gray to yellow, deeply altered andesite that forms plugs, dikes, and small vent complexes on Mount Rainier

PLEISTOCENE-PLIOCENE INTRUSIVE ROCKS

Intermediate

QPida **Intrusive dacite**—Dacite domes and plugs; at Goat Mountain, southwest of Mount St. Helens, light-gray biotite-hornblende-quartz dacite porphyry plug; at Gross Mountain east of the Little White Salmon River, light-gray porphyritic hypersthene dacite. Includes Goat Mountain plug (Hammond, 1980) and dacite dome of Gross Mountain (Sheppard, 1964)

QPian **Intrusive andesite**—Plugs and dikes of pyroxene andesite, basaltic andesite, and hornblende andesite of the Goat Rocks area

PLIOCENE INTRUSIVE ROCKS

Intermediate

Pida **Intrusive dacite**—Porphyritic dacite domes, plugs, and stocks; northeast of the Goat Rocks, consists of several small stocks and plugs of pale brown to gray, fine- to medium-grained biotite-hornblende dacite; between the Wind and Little White Salmon Rivers, dacite forms a hypabyssal stock at Hauk Butte and a hornblende dacite to porphyritic diorite stock north of Wind Mountain; in the Simcoe Mountains, light- to dark-gray olivine-hypersthene-clinopyroxene dacite domes

Piq **Quartz diorite**—Light-gray to brownish-gray, porphyritic hypersthene-biotite-quartz diorite, and hornblende-quartz diorite forming a composite plug, and hornblende diorite; contains xenoliths of Grande Ronde Basalt (unit Mv$_g$). Consists of the Wind Mountain quartz diorite (Wise, 1970)

Pian **Intrusive andesite**—Shallow stocks and plugs of hornblende andesite; may be of late Miocene age

MIOCENE INTRUSIVE ROCKS

Acidic

Mir **Intrusive rhyolite**—Rhyolite dikes, sills, plugs, domes, and shallow stocks; commonly white to tan, fine-grained felsite; may contain welded tuffs; in the Bumping Lake area, coarsely porphyritic rhyolite with phenocrysts of biotite, hornblende, and quartz; at Clear West Peak, mostly gray to purple, highly altered, sparsely plagioclase-phyric, devitrified rhyolite with vertical banding (suggesting intrusive origin); at Mann Butte, grayish-yellow aphanitic rhyolite forming a pervasively brecciated plug or dome; at Spud Hill, white to gray, unaltered, aphyric, microcrystalline biotite-quartz rhyolite plug. Includes Clear West complex (Fischer, 1970) and rhyolite of Mann Butte (Hammond, 1980)

Mia **Acidic intrusive rocks**—Sills, dikes, plugs, and stocks of acidic composition, including granite, granodiorite, and quartz monzonite; at Mount Rainier, light-colored hypabyssal intrusive rock gradational from diorite to quartz monzonite, dominantly granodiorite and quartz monzonite. Includes the Bumping Lake pluton (Simmons and others, 1983), part of the Tatoosh pluton (Fiske and others, 1963), and argillically altered parts of the Spirit Lake pluton (Evarts and Ashley, 1984)

Mig **Granite**—Medium-grained equigranular and porphyritic granite. Consists of part of the Tatoosh pluton (Fiske and others, 1963)

Miqm **Quartz monzonite**—Fine- to medium-grained quartz monzonite; north of Mount St. Helens, fine- to medium-grained, commonly deuterically altered, sparsely porphyritic and miarolitic pyroxene-hornblende quartz monzonite, granite, and aplite; in Mount Rainier area, fine-grained biotite-hornblende quartz monzonite; locally porphyritic. Includes part of the Spirit Lake pluton (Evarts and Ashley, 1984) and part of the Tatoosh pluton (Fiske and others, 1963)

Migd **Granodiorite**—Porphyritic to equigranular, fine- to medium-grained, hornblende-biotite or pyroxene granodiorite and lesser quartz monzonite and quartz diorite; north of Spirit Lake, consists of complex dike swarms of deuterically altered granodiorite and quartz diorite with numerous screens of hornfelsed country rock. Includes the White River pluton (Hammond, 1980), the Carbon River stock (Fischer, 1970), and part of the Silver Star pluton (Felts, 1939), part of the Tatoosh pluton (Fiske and others, 1963), and part of the Spirit Lake pluton (Evarts and Ashley, 1984)

Intermediate

Mida **Intrusive dacite**—Gray porphyritic hornblende and pyroxene dacite sills, dikes, domes, and small or shallow stocks; commonly altered

Miq **Quartz diorite**—Equigranular to porphyritic quartz diorite; at Silver Star Mountain, uralitized pyroxene quartz diorite; north of Spirit Lake, pyroxene quartz diorite to quartz monzonite bodies that have subtle, gradational contacts and pervasive deuteric alteration; forms smaller quartz diorite bodies in the Cascades. Includes McCoy Creek quartz diorite (Link, 1985), part of the Silver Star pluton (Felts, 1939), part of the Spirit Lake pluton (Evarts and Ashley, 1984), and part of the Tatoosh pluton (Fiske and others, 1963)

Mian **Intrusive andesite**—Dark- to medium-gray, aphanitic to porphyritic pyroxene and hornblende andesite and basaltic andesite; forms numerous dikes, sills, small plugs, and stocks throughout the Cascades

Mid **Diorite**—Fine- to medium-grained and commonly porphyritic pyroxene diorite, pyroxene-hornblende diorite, and hornblende diorite; occurs as sills, dikes, small stocks, and cupolas of major plutons; contains lesser quartz diorite. Includes Saturday Rock pluton (Hammond, 1980) and part of the Silver Star pluton (Felts, 1939)

Basic

Mib **Basic intrusive rocks**—Fine-grained to aphanitic basalt and basaltic andesite sills and dikes

Migb **Gabbro**—Diabase and gabbro sills, dikes and stocks; at Box Canyon near Mount Rainier, forms a large sill complex of dark-colored glomeroporphyritic augite diabase and minor basalt; north of Wind Mountain, forms a dark gray to black porphyritic plagioclase-hypersthene gabbro plug; at Bunker Hill in the Wind River valley, forms a black, coarse-grained augite gabbro plug that has a deuterically altered margin

Intrusive-Volcanic Complex

Miv **Intrusive-volcanic complex**—Intrusive and extrusive dacitic vitrophyres and breccias; breccias are highly altered and partially recrystallized; vitrophyres include glassy flows and probable welded tuffs; these rocks are cut by a silicic sill swarm that may not be related to the original complex activity. Consists of Skyscraper Mountain complex (Thompson, 1983)

MIOCENE-OLIGOCENE INTRUSIVE ROCKS

Intermediate

MƟida **Intrusive dacite**—White to light-gray, aphyric to plagioclase-hornblende-phyric, commonly altered dacite sills, dikes, domes, and small stocks

MƟian **Intrusive andesite**—Aphyric to porphyritic hornblende-, pyroxene-, and hornblende-pyroxene andesite stocks, sills, dikes, and dike swarms; commonly altered

MƟid **Diorite**—Porphyritic pyroxene- and hornblende-diorite dikes and stocks; commonly altered

Basic

MƟib **Basic intrusive rocks**—Aphanitic and plagioclase-phyric basalt, augite, and hypersthene-augite diabase and porphyritic pyroxene gabbro dikes and sills

Intrusive-Volcanic Complex

MƟiv **Intrusive-volcanic complex**—Thick, heterogeneous, and disrupted assemblage of volcanic rocks, including andesite porphyry flows, interbedded volcaniclastic rocks, and dacitic tuffs and breccias with both extrusive and intrusive characteristics. Consists of the Mount Aix volcanic complex (Schreiber, 1981)

EOCENE INTRUSIVE ROCKS

Acidic

Eiqm **Quartz monzonite**—Two-phase stock consisting of blocky jointed granophyric, porphyritic quartz monzonite and granodiorite. Consists of the Ordway Creek stock (Livingston, 1966)

Intermediate

Eida **Intrusive dacite**—Fine-grained, granular, glomeroporphyritic, hornblende hypersthene dacite porphyry. Consists of andesite of Peoh Point (Tabor and others, 1982)

Basic

Eib **Basic intrusive rocks**—Gabbro, diabase, and basalt dikes and sills; in the Willapa Hills, flow-banded and vesicular sill complex whose interiors are columnar-jointed basalt; south of Cle Elum and on Teanaway Ridge, black, fine- to medium-grained clinopyroxene diabase and gabbro dikes; elsewhere, small gabbro, diorite, diabase, and basalt intrusions

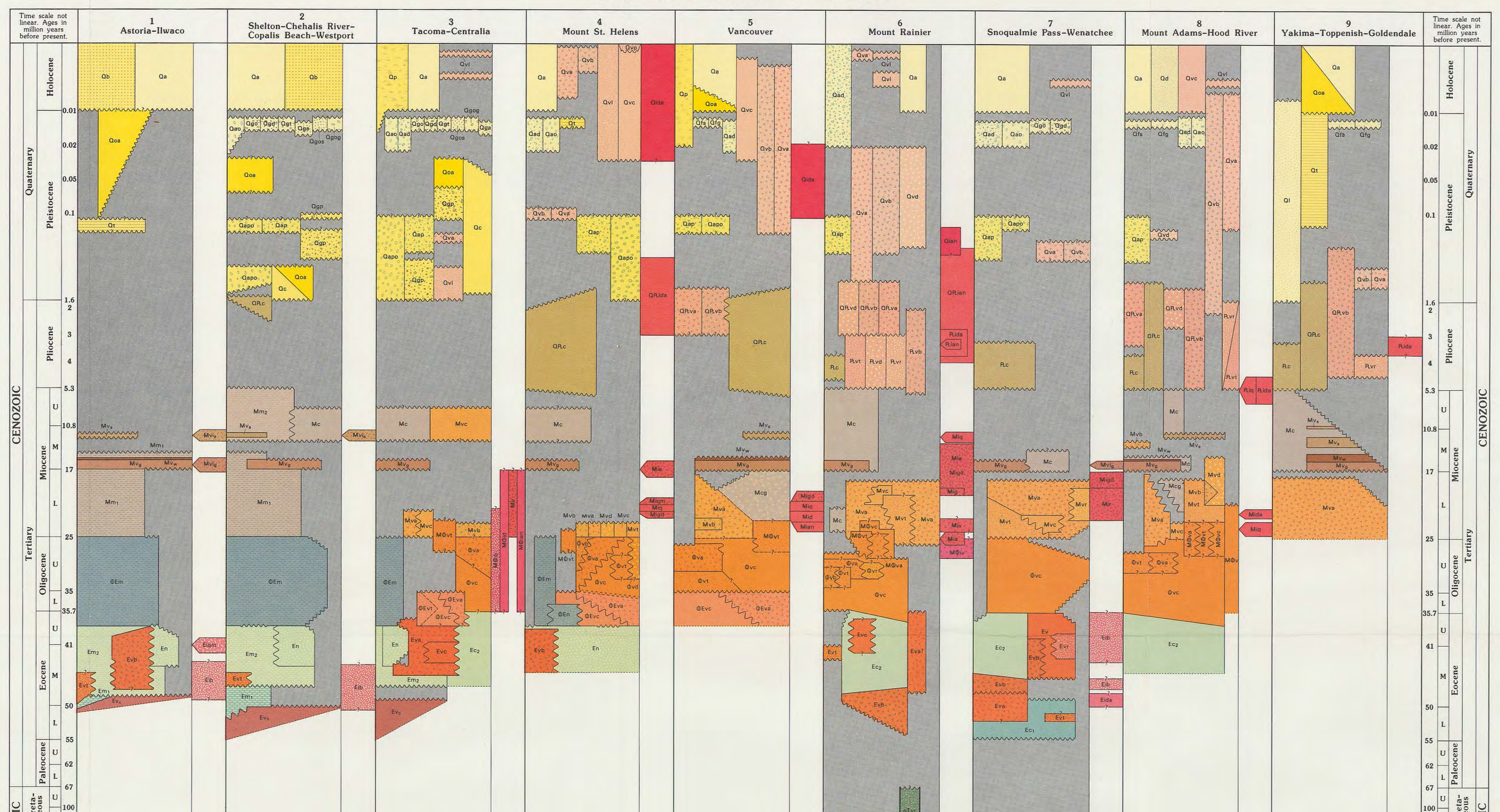
JURASSIC INTRUSIVE ROCKS

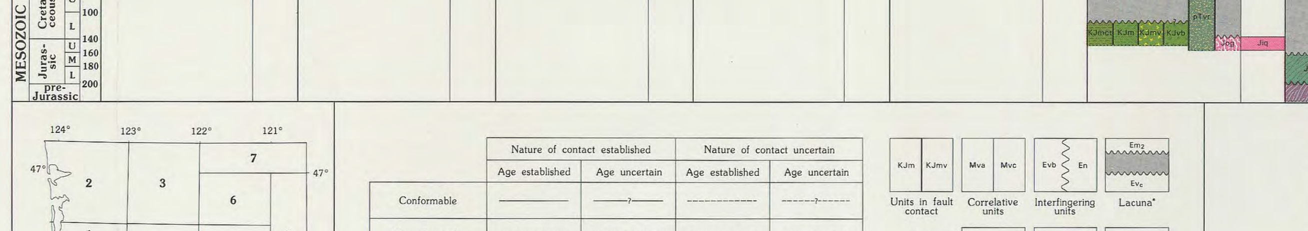
Intermediate

Jiq **Upper Jurassic quartz diorite**—At Quartz Mountain medium-grained hornblende meta-quartz-diorite and metagranodiorite stock; near White Pass, minor diorite and gabbro intruded by voluminous quartz diorite, which is in turn intruded by trondhjemite dikes; some intrusions are weakly foliated. Consists of Quartz Mountain quartz diorite (Goetsch, 1978), parts of the Indian Creek complex (Miller, 1985), and the Peninsula tonalite (Swanson, 1964)

* See pamphlet for intrusive rock classification.

STRATIGRAPHIC COLUMNS





NOTES

Each column depicts stratigraphic relations for major time-lithologic units (map units, defined in the **Descriptions of Map Units**, left) used on the geologic map over a specific geographic area. The area covered by each column is shown diagrammatically in the lower left of this diagram.

The relationships depicted in the columns have been compiled from many sources and do not represent any single exposure.

Omitted from the columns because of diagram scale are Quaternary landslide deposits, poorly defined units, several small and poorly dated intrusive bodies, and several volcanic units of limited areal extent in the Cascade Mountains. Space limitations prohibited detailed portrayal of contacts for most Quaternary and some Pliocene units. Although many of these units rest unconformably on older units, this is not shown in all the columns.

Each stratigraphic column shows age ranges in restricted areas; in contrast, the **Correlation Diagram** (below) depicts age ranges for the entire map area. In addition, the age ranges shown on the Correlation Diagram do not everywhere agree with the age ranges of map units on these stratigraphic columns because some map units consist of several named units or parts of named units.

Chart format is modified from Armentrout and others (1983). The diagram time-rock scale is from Salvador (1985), with boundary-age modifications of Montanari and others (1985) and Aguirre and Pasini (1985). Biostratigraphic zonations are after Armentrout (1981) and Armentrout and others (1983). Further discussion and references are given in the pamphlet.

CORRELATION DIAGRAM

The diagram time-rock scale is from Salvador (1985), with boundary-age modifications of Montanari and others (1985) and Aguirre and Pasini (1985). Biostratigraphic zonations are after Armentrout (1981) and Armentrout and others (1983).

[1] Kleinpell and others, 1980; Mallory, 1959
[2] Rau, 1981
[3] Addicott, 1976; Armentrout, 1981
[4] Wolfe, 1981

** Placement of the Refugian, Galvinian, and Kummerian boundaries follows Armentrout and Prothero (1984).

† Full spellings of abbreviations, this column: *Baggina washingtonensis, Vaginulinopsis vacavillensis, Cassidulina galvinensis.*

This diagram shows maximum probable age ranges for the geologic map units (time-lithologic units, defined in the **Descriptions of Map Units**, left) and for their component formal and selected informal named geologic units. The **List of Named Units** (right) shows all map units in which a named unit is included.

Upper and lower age limits are queried where uncertain. Dashed lines indicate possible extensions of age ranges beyond limits directly indicated by available geologic data.

See the pamphlet for further explanation.

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

LIST OF NAMED UNITS

GEOLOGIC UNIT	SYMBOL	DEFINING AND/OR REPRESENTATIVE REFERENCES	COUNTY	AREA
Alderton Formation	Qc	Crandell, 1963	Pierce	Puyallup River; T19N,R4-5E
Amboy drift	Qap Qapo	Mundorff, 1964, 1984	NE Clark	E and N Forks of Lewis River
Asotin Member of the Saddle Mountains Basalt	Mv$_s$	Swanson and others, 1979b	Yakima	Yakima; T13N,R18E
Astoria Formation	Mm$_1$	Weaver, 1937; Wolfe and McKee, 1972; Niem and Niem, 1985; Rau, 1967, 1986		W half of map
Balch Lake, basalt porphyry of	QPvb	Newcomb, 1969	SW Klickitat	Klickitat-Columbia R. confluence; T3N,R12E
Bee Flat, andesite of	QPva	Fiske and others, 1963	E central Pierce	N-NW side Mount Rainier; T17N,R8E
Bethel Ridge, olivine basalt of	Pvb	Swanson, 1978	N central Yakima	NE Rimrock Lake; T14N,R13E
Boring Lava	QPva QPvb	Griffin and others, 1956; Trimble, 1957	Clark, SW Skamania	Camas, Skamania, Battle Ground
Bumping Lake pluton	Mia	Abbott, 1953; Hammond, 1980; Simmons and others, 1983	NW Yakima	Bumping Lake
Bumping River tuff	MƟvt	Warren, 1941; Hammond, 1980	NW Yakima	Bumping and American Rivers; T17N,R13E
Burnt Mountain, tuff of	MƟvt	Swanson, 1978	NW Yakima	N of Tieton River; T14N,R13E
Burroughs Mountain Drift	Qad	Crandell and Miller, 1964; Crandell, 1969	E central Pierce	N flank of Mount Rainier
Butte Camp dome	Qida	Hopson, 1980	Skamania	SW flank of Mount St. Helens; T8N,R5E
Cape Foulweather Basalt	Mv$_w$	Snavely and others, 1973; Beeson and others, 1979	Wahkiakum, W Cowlitz	Columbia River W of Longview
Carbon River stock	Migd	Fischer, 1970; Frizzell and others, 1984	Central Pierce	WNW of Mount Rainier; T17-18N,R7-8E
Carbonado Formation	Ec$_2$	Weaver, 1937; Gard, 1968	Pierce	NW of Mount Rainier, Carbon River
Cave Basalt	Qvb	Greeley and Hyde, 1972	NW Skamania	S side Mount St. Helens; T7-8N,R4-5E
Chambers Creek, beds of	Ec$_2$	Winters, 1984	E Lewis	SE of Packwood; T11-12N,R10E
Chow Chow drift	Qao	Moore, 1965	NW Grays Harbor	Extreme NW corner of map
Clear West complex	Mir	Fischer, 1970; Frizzell and others, 1984	N central Pierce	N of Mount Rainier; T18N,R8E
Cliff Point, siltstone of	Em$_2$	Wells, 1979; Wells, in press	Pacific	Naselle River area
Columbia River Basalt Group	Mv$_s$ Mv$_w$ Mv$_g$ Mvi$_s$ Mvi$_g$	Swanson and others, 1979b		E, W, and S perimeter of map
Colvos Sand	Qga	Garling and others, 1965; Noble and Wallace, 1966	NW Pierce	Southern Puget Sound shorelines
Council Bluff, lava flows of	Mva	Harle, 1974; Hammond, 1980	N Skamania	Between Mount St. Helens and Mount Adams
Cowlitz Formation	Em$_2$ En Evt	Weaver, 1937; Henriksen, 1956; Livingston, 1966; Wells, 1981; Niem and Niem, 1985		SW part of map
Crescent Formation	Em$_1$ Ev$_c$	Weaver, 1937; Rau, 1967; Wells and Coe, 1985		W 1/3 of map
Dalles Formation	Mc	Newcomb, 1966, 1969	S Klickitat	N of The Dalles; T2N,R13-14E
Damon silt	Qc	Moore, 1965	W Grays Harbor	N of Grays Harbor
Depoe Bay Basalt	Mv$_g$ Mvi$_g$	Snavely and others, 1973; Beeson and others, 1979		W side of map
Devils Horns rhyolite	Pvr	Clayton, 1983	W central Yakima	Goat Rocks; T12N,R11-12E
Devils Washbasin basalt	Pvb	Clayton, 1983	W central Yakima	Goat Rocks; T12N,R11-12E
Eagle Creek Formation	Mcg	Wise, 1961, 1970	S and S cen. Skamania	N of North Bonneville, N of Indian Heaven
Eagle Gorge, volcanic rocks of	Mva Mvt	Hammond, 1963; Frizzell and others, 1984	SE King	N of Mount Rainier; T20N,R8-9E
Easton Schist	Jph Jsh	Smith, 1903; Frizzell and others, 1984	W Kittitas	N flank Manastash Ridge; T19-20N,R14-15E
Electron Mudflow	Qvl	Crandell, 1971	Central Pierce	Puyallup R.; T18-19N,R5E; T16-17N,R6-7E
Elephant Mountain Member of the Saddle Mountains Basalt	Mv$_s$	Swanson and others, 1979b	Yakima	Toppenish Ridge; T9N,R18E
Ellensburg Formation	Mc Mvc	Waitt, 1979; Swanson and others, 1979b	Kittitas, Klickitat, Yakima	E and SE map area
Evans Creek Drift	Qad Qao	Crandell, 1963		W Cascade Mountains
Fifes Peak Formation	Mva	Warren, 1941; Swanson, 1978; Fiske and others, 1963; Frizzell and others, 1984; Carkin, 1985	NW Yakima, SE King, NE Pierce	Mount Rainier-Bumping Lake, Tieton River
Frenchman Springs Member of the Wanapum Basalt	Mv$_w$	Swanson and others, 1979b		E, W, and S perimeter of map
Frost Mountain, basalt of	Evb	Tabor and others, 1984	W Kittitas	Frost Mountain; T18N,R15E
Garda Drift	Qad	Crandell and Miller, 1964, 1974; Crandell, 1969	SE Pierce	On Mount Rainier
Goat Mountain plug	QPida	Hammond, 1980	W Skamania	SW of Mount St. Helens; T8N,R4E
Goble Volcanics Member of the Cowlitz Formation	Evb	Henriksen, 1956; Phillips, 1987a	Cowlitz	Castle Rock; T10N,R2W
Goble Volcanics	ƟEva ƟEvc	Wilkinson and others, 1946; Livingston, 1966	Cowlitz, E Wahkiakum	Longview
Grande Ronde Basalt	Mv$_g$ Mvi$_g$	Swanson and others, 1979b; Mangan and others, 1986		E, W, and S perimeter of map
Grays River volcanic rocks	Evb	Phillips, 1987a; Walsh, 1987a	Cowlitz, Pacific, Wahkiakum	
Greenwater lahar	Qvl	Crandell, 1971	NE Pierce, SE King	White River at Greenwater; T19N,R9E
Gross Mountain, dacite dome of	QPida	Sheppard, 1964	W Klickitat	SW of Trout Lake; T5N,R11E
Hatchet Mountain Formation	ƟEva ƟEvc	Roberts, 1958; Phillips and Kaler, 1985	N Cowlitz	Hatchet Mountain
Hayden Creek Drift	Qap Qapo	Crandell and Miller, 1974		W Cascade Mountains
Helm Creek drift	Qgp	Carson, 1970	Grays Harbor	Lower Chehalis River; T17-20N,R6-7W
Hicks Butte, tonalite gneiss of	Jog	Frizzell and others, 1984	W Kittitas	S Cle Elum Ridge; T19N,R14E
Hogback Mountain, mafic rocks of	QPvb	Clayton, 1983	NW Yakima, SE Lewis	White Pass; T13-15N,R11E
Hoh Assemblage	Em$_1$	Rau, 1973, 1986	W Grays Harbor	N of Grays Harbor; T19N,R10-11W
Huckleberry Mountain, volcanic rocks of	Ɵvc	Hammond, 1963; Frizzell and others, 1984	SE King, W Kittitas, NE Pierce	N of Mount Rainier
Humptulips Formation	Em$_2$	Rau, 1984, 1986	W Grays Harbor	N of Grays Harbor; T19-20N,R9-10W
Humptulips drift	Qap Qapo	Moore, 1965	W Grays Harbor	N of Grays Harbor; T20N,R10-12W
Indian Creek complex	Jiq Jog	Clayton, 1983; Miller, 1985	NW Yakima	Near Rimrock Lake
Kalama River dome	Qida	Hopson, 1980	Skamania	Near headwaters of Kalama River; T8N,R4E
Kitsap Formation	Qc	Sceva, 1957; Garling and others, 1965	N Thurston, E Mason, NW Pierce	S Puget Sound shorelines
Kittitas Drift	Qap Qapo Qt	Porter, 1976; Waitt, 1979; Tabor and others, 1982	Kittitas, Yakima	E slope Cascade Mountains
Lakedale Drift	Qad Qao Qt	Porter, 1976; Waitt, 1979	Kittitas, Yakima	E slope Cascade Mountains
Lily Creek Formation	Qvl	Crandell, 1963; Crandell and Miller, 1974	N central Pierce	E of Lake Kapowsin; T17N,R5E
Lincoln Creek Formation	ƟEm	Rau, 1966; Beikman and others, 1967; Armentrout, 1973; Prothero and Armentrout, 1985		W 1/2 of map
Lincoln Plateau, basalt of	QPvb	Sheppard, 1967	W Yakima	NE of Mount Adams; T9N,R13-14E
Logan Hill Formation	Qapo	Snavely and others, 1958; Roberts, 1958	N Cowlitz, Lewis, SW Thurston	W central part of map area
Lookout Creek sandstone	Ec$_2$	Schreiber, 1981	NW Yakima	Between Bumping & Rimrock Lakes; T15N,R13E
Lookout Mountain Formation	pJsc	Stout, 1964; Frizzell and others, 1984	W Kittitas	Manastash Ridge; T18-19N,R14E
Lookout Mountain Ranch Drift	Qap	Waitt, 1979	Kittitas	Cle Elum area; T19N,R16-17E
Manastash Formation	Ec$_1$	Weaver, 1937; Tabor and others, 1984	SW Kittitas	Manastash Ridge; T18-19N,R14-15E
Mann Butte, rhyolite of	Mir	Hammond, 1980	SE Skamania	SW of Trout Lake; T5N,R9E
Mashel Formation	Mc	Walters and Kimmel, 1968	SW Pierce	Nisqually River; T16-17N,R3-4E
McCoy Creek quartz diorite	Miq	Simon, 1972; Link, 1985	N Skamania	Between Cispus & Lewis Rivers; T10N,R8E
McDonald Ridge drift	Qad	Hopkins, 1976	E Skamania, SW Yakima	Mount Adams
McIntosh Formation	Em$_1$ Em$_2$	Snavely and others, 1951, 1958; Wagner, 1967a		W central part of map
McNeely Drift	Qad	Crandell, 1969; Crandell and Miller, 1974	SE Pierce	N slope of Mount Rainier
Megler, sandstone of	Em$_1$	Wells, 1979; Wells, in press	SW Pacific	Mouth of Columbia River
Midway, tuff at	Pvt	Hammond, 1980	NE Skamania	NNW of Mount Adams; T10N,R10E
Milk Creek, olivine basalt of	Ɵvb	Swanson, 1978	W central Yakima	SE of Rimrock Lake; T13N,R14E
Milk Creek, tuff of	Ɵvt	Swanson, 1978	W central Yakima	SE of Rimrock Lake; T13N,R14E
Missoula flood deposits, glacial Lake	Qfg Qfs	Trimble, 1963; Bretz, 1969; Waitt, 1980	S Klickitat, Clark	Columbia River
Mobray drift	Qap	Carson, 1970	E Grays Harbor	NE of Grays Harbor; T20N,R7-8W
Montesano Formation	Mm$_2$	Weaver, 1916; Rau, 1967		NW quarter of map
Mount Adams, andesites of	Qva	Hammond, 1980; Hildreth and others, 1983	Skamania, Yakima	Mount Adams
Mount Aix volcanic complex	MƟiv	Schreiber, 1981; Vance and others, in press	NW Yakima	SE of Bumping Lake; T15N,R12-13E
Mount Rainier, andesites of	Qva	Fiske and others, 1963	E Pierce	Mount Rainier
Mount Rainier, vent complexes on	Qian	Fiske and others, 1963	E Pierce	Mount Rainier
Mount St. Helens 1980 debris avalanche	Qls	Lipman and Mullineaux, 1981	Skamania	Mount St. Helens
Mount St. Helens 1980 lahars	Qvl	Lipman and Mullineaux, 1981	Skamania, N Cowlitz	Mount St. Helens, Toutle River
Mount St. Helens 1980 pumice flows	Qvp	Lipman and Mullineaux, 1981	Skamania	Mount St. Helens
Mount St. Helens pre-1980 lahars	Qvl	Scott, 1986	Cowlitz	Toutle and Kalama Rivers
Mount St. Helens pre-1980 volcaniclastic deposits	Qvc	Hopson, 1980	Skamania, E Cowlitz	Mount St. Helens
Mount St. Helens, Holocene domes on	Qida	Hopson, 1980	Skamania	Mount St. Helens
Mount St. Helens, andesites of	Qva	Hopson, 1980	Skamania	Mount St. Helens
Mount St. Helens, basalts of	Qvb	Hopson, 1980	Skamania	Mount St. Helens
Muddy River lahar	Qvl	Lipman and Mullineaux, 1981	Skamania	Mount St. Helens
N_1 magnetostratigraphic unit of the Grande Ronde Basalt	Mv$_g$	Swanson and others, 1979b	Skamania	Dog Mountain; T3N,R9E
N_2 magnetostratigraphic unit of the Grande Ronde Basalt	Mv$_g$	Swanson and others, 1979b		W, S, and E perimeter of map
Naches Formation	Ec$_2$ Ev Evb Evr	Weaver, 1937; Stout, 1964; Tabor and others, 1984	NE corner of map	Naches River-Manastash Ridge
Northcraft Formation	Eva Evc ƟEva ƟEvc ƟEvt	Snavely and others, 1958; Gard, 1968; Buckovic, 1974; Hammond, 1980; Hagen, 1987	Pierce, Lewis, Thurston	N central part of map
Ohanapecosh Formation	Ɵva Ɵvc Ɵvr	Fiske and others, 1963; Hammond, 1980; Vance and others, in press	E Lewis, E Pierce, NW Yakima	Cascade Mountains, White River to Cispus River
Olequa Creek Member of the Cowlitz Formation	En	Henriksen, 1956	W Cowlitz and Lewis	Vader area
Omeara Point, siltstone and sandstone at	Em$_2$	Wells, in press	Pacific	Mouth of Columbia River
Ordway Creek stock	Eiqm	Livingston, 1966	W Cowlitz	NW of Longview; T10N,R4W
Orting Drift	Qgp	Crandell, 1963	N central Pierce	Puyallup River; T19N,R5E
Osceola Mudflow	Qvl	Crandell and Waldron, 1956; Crandell, 1963, 1971	NE Pierce, S central King	White River, N and NW of Mount Rainier
Pack Sack Lookout, basalt of	Mv$_s$ Mvi$_s$	Snavely and others, 1973; Beeson and others, 1979; Magill and others, 1982	Pacific, Wahkiakum	SW part of map
Palisades, welded tuff of The	Mvt	Fiske and others, 1963	SE Pierce	NE flank of Mount Rainier; T17N,R9E
Paradise debris flow	Qvl	Crandell, 1969, 1971	SE Pierce	S flank of Mount Rainier; T15N,R8E
Pe Ell Volcanics Member of the Cowlitz Formation	Evt	Henriksen, 1956	W Lewis, SE Pacific	Upper Chehalis River; T12-13N,R5W
Peninsula tonalite	Jiq	Swanson, 1978	W central Yakima	E end of Rimrock Lake; T13N,R13-14E
Peoh Point, andesite of	Eida	Tabor and others, 1982	SW Kittitas	S Cle Elum Ridge; T19N,R15E
Pine Creek lahar	Qvl	Lipman and Mullineaux, 1981	Skamania	SE flank of Mount St. Helens
Pomona Member of the Saddle Mountains Basalt	Mv$_s$ Mvi$_s$	Swanson and others, 1979b (See also basalt of Pack Sack Lookout)		E, W, and S perimeter of map
Priest Rapids Member of the Wanapum Basalt	Mv$_w$	Swanson and others, 1979b	Klickitat, Yakima	SE corner of map
Puget Group	Ec$_2$	Weaver, 1937; Fisher, 1957; Gard, 1968; Wolfe, 1968		W Cascade foothills, Bumping River
Puyallup Formation	Qc	Crandell, 1963	Pierce	Puyallup River valley; T19N,R5E
Quartz Mountain quartz diorite	Jiq	Goetsch, 1978; Frizzell and others, 1984	SW Kittitas	Manastash Ridge; T18N,R14E
R_1 magnetostratigraphic unit of the Grande Ronde Basalt	Mv$_g$	Swanson and others, 1979b	Skamania	Dog Mountain; T3N,R9E
R_2 magnetostratigraphic unit of the Grande Ronde Basalt	Mv$_g$	Swanson and others, 1979b		E, S, and W perimeter of map
Randle laharic breccia-conglomerate	Mvc	Fisher, 1960	E central Lewis	NW of Randle along Cowlitz R.; T12N,R7E
Rattlesnake Creek tuff	MƟvt	Schreiber, 1981; Vance and others, in press	NW Yakima	Between Naches & Tieton Rivers; T15N,R14E
Roslyn Formation	Ec$_2$	Weaver, 1937; Walker, 1980; Tabor and others, 1982, 1984	W central Kittitas	Roslyn-Cle Elum area; T20N,R15-17E
Roza Member of the Wanapum Basalt	Mv$_w$	Swanson and others, 1979b	Klickitat, Yakima	E and SE parts of map
Russell Ranch Formation	KJm KJmct KJmv KJvb pTvr	Swanson, 1978; Clayton, 1983; Miller, 1985	NW Yakima, NE Lewis	Rimrock Lake, White Pass, Mount Aix
Saddle Mountains Basalt	Mv$_s$ Mvi$_s$	Swanson and others, 1979b; Reidel and Fecht, 1981		E, W, and S perimeter of map
Salmon Springs Drift	Qgp	Crandell and others, 1958; Easterbrook and others, 1981	Pierce	Puyallup River valley; T20N,R4-5E
Saturday Rock pluton	Mid	Hammond, 1980	W central Skamania	E fork Lewis River-Canyon Creek; T4N,R5E
Shoalwater Bay, siltstone at	Em$_2$	Wells, in press	Pacific	Mouth of Columbia River
Silver Star pluton	Mid Migd Miq	Felts, 1939; Schriener, 1978; Shepard, 1980	SW Skamania	Silver Star Mountain; T3N,R4-5E
Simcoe Mountains, volcanic rocks of	Pvr QPvb	Sheppard, 1960, 1967	W Klickitat, SW Yakima	SE corner of map
Skamania volcanic rocks	Ɵva	Trimble, 1963	Central Skamania, E Clark	NE of Camas
Skamokawa Creek, siltstone of	Em$_2$	Wells, 1981	NE Wahkiakum	Skamokawa; T10N,R6W
Skokomish Gravel	Qoa	Molenaar and Noble, 1970	NE Pierce, E Mason, Thurston	SW Puget Sound
Skookumchuck Formation	En	Snavely and others, 1958	S Thurston, W Lewis	Centralia-Chehalis
Skyscraper Mountain complex	Miv	Fiske and others, 1963; Thompson, 1983	SE Pierce	E flank of Mount Rainier; T17N,R9E
Spencer Creek, sandstone of	Ɵvc	Swanson, 1964, 1978	W central Yakima	SE of Rimrock Lake; T13N,R14E
Spencer Creek, welded tuff at	Evt	Swanson, 1964, 1978	W central Yakima	SE of Rimrock Lake; T13N,R14E
Spiketon Formation	Ec$_2$	Gard, 1968	Central Pierce, E Lewis	Cascade foothills W of Mount Rainier
Spirit Lake pluton	Mia Migd Miq Miqm	Evarts and Ashley, 1984; Evarts and others, in press	N Skamania	N of Spirit Lake
Steilacoom Gravel	Qgog	Walters and Kimmel, 1968	W Pierce	SE Puget Sound
Stevens Ridge Formation	MƟvt Mvt	Fiske and others, 1963; Frizzell and others, 1984	SE Pierce, NE Lewis	Mount Rainier area
Stevenson Ridge lavas	Mva	Berri and Korosec, 1983	S Skamania	N of Stevenson; T3N,R7-8E
Stillwater Creek Member of the Cowlitz Formation	Em$_2$	Henriksen, 1956	W Cowlitz, Lewis	Ryderwood
Stuck Drift	Qgp	Crandell, 1963	Pierce	Puyallup River valley; T19N,R4-5E
Summit Creek sandstone	Ec$_2$	Ellingson, 1959; Vance and others, in press	NE Lewis	Summit Creek; T14N,R10E
Summit Creek, basalt of	Evb	Ellingson, 1959; Vance and others, in press	NE Lewis	Carlton Ridge; T14-15N,R11E
Swale Creek valley, sedimentary deposits of	QPc	Newcomb, 1969	S Klickitat	SW of Goldendale; T3N,R14-16E
Swauk Formation	Ec$_1$	Tabor and others, 1984	NW and N Kittitas	N of Yakima River; T20N,R17-18E
Taneum Formation	Eva	Warren, 1941; Tabor and others, 1984	NW Kittitas	Manastash Ridge area; T19N,R14-15E
Tatoosh pluton	Mia Mig Migd Miq Miqm	Wright, 1960; Fiske and others, 1963; Thompson, 1983	SE Pierce, NW Lewis	Mount Rainier
Teanaway Formation	Evb	Tabor and others, 1982, 1984	NE Kittitas	NE of Teanaway River; T20N,R17-18E
Thorp Gravel	Pc	Waitt, 1979; Tabor and others, 1982	Kittitas	Northeast corner of map
Three Corner Rock, lava flows of	Mva	Hammond, 1980	SW Skamania	N of Skamania; T2-3N,R6E
Tieton Andesite	Qva	Smith, 1903; Swanson, 1978; Clayton, 1983	W Yakima	Naches and Tieton Rivers
Toutle Formation	ƟEn	Roberts, 1958; May, 1980	N Cowlitz	Toutle River; T10-11N,R1W-1E
Toutle River lahars	Qvl	Lipman and Mullineaux, 1981	Skamania, Cowlitz	Along Toutle River W of Mount St. Helens
Trout Lake mudflow	Qvl	Hopkins, 1976	NW Yakima, E Skamania	Along White Salmon River; T6N,R10E
Troutdale Formation	QPc	Trimble, 1963; Mundorff, 1964; Livingston, 1966; Tolan and Beeson, 1984	Clark, SW Cowlitz	Along Columbia River
Tumtum Mountain, Pleistocene dome at	Qida	Mundorff and Eggers, in press	NE Clark	SSW of Yale Reservoir; T5N,R4E
Umatilla Member of the Saddle Mountains Basalt	Mv$_s$	Swanson and others, 1979b	Yakima	E side of map
Unit A of Wolfe and McKee (1972)	Em$_1$	Wolfe and McKee, 1972	Pacific, Wahkiakum	Naselle River; T11N,R8W
Unit B of Wolfe and McKee (1972)	Em$_2$ Evb ƟEm	Wolfe and McKee, 1972	Pacific, Wahkiakum	Naselle River; T11N,R8W
Vashon Drift	Qga Qgd Qgo Qgog Qgos Qgt	Crandell and others, 1958; Armstrong and others, 1965		S Puget Sound lowland
Wanapum Basalt	Mv$_w$	Swanson and others, 1979b; Beeson and others, 1985		E, W, and S perimeter of map
Weatherwax formation	Qapo	Carson, 1970	E Grays Harbor	Satsop River; T20N,R7W
Wedekind Creek formation	Qapo	Carson, 1970	Grays Harbor	Montesano
White River pluton	Migd	Fiske and others, 1963; Hammond, 1980; Thompson, 1983	E Pierce	White River; T16-17N,R9-10E
White River rheoignimbrite	Mvr	Fischer, 1970; Frizzell and others, 1984	Central Pierce	NNW of Mount Rainier; T19N,R8E
White Salmon drift	Qap	Hopkins, 1976	W Klickitat	Along White Salmon River; T7N,R10E
Wilbur Creek Member of the Saddle Mountains Basalt	Mv$_s$	Swanson and others, 1979b	Yakima	Yakima; T13N,R18E
Wildcat Creek, tuffaceous rocks of	Ɵvc	Swanson, 1978; Vance and others, in press	NW Yakima	Bumping-Tieton Rivers; T14N,R13E
Wilkes Formation	Mc	Roberts, 1958	N Cowlitz, W Lewis	W central part of map
Wind Mountain quartz diorite	Piq	Wise, 1961, 1970; Free, 1976	S Skamania	Columbia River SE of Carson; T3N,R8E
Wingate Hill Drift	Qap Qapo	Crandell, 1963; Crandell and Miller, 1974		Cowlitz River and W central Cascade Range
Yakima Basalt Subgroup	Mv$_s$ Mv$_w$ Mv$_g$ Mvi$_s$ Mvi$_g$	Swanson and others, 1979b		E, W, and S perimeter of map