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**GEOLOGIC MAP OF THE  
SPOKANE 1:100,000 QUADRANGLE,  
WASHINGTON - IDAHO**

**Compiled by  
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**WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES**

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This report has not been edited or reviewed for conformity with  
Division of Geology and Earth Resources standards and nomenclature

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**Natural Resources**

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# GEOLOGIC MAP OF THE SPOKANE 1:100,000 QUADRANGLE, WASHINGTON-IDAHO

compiled by  
Nancy L. Joseph

## INTRODUCTION

The Spokane quadrangle is one of sixteen complete or partial 1:100,000-scale quadrangles that cover the northeast quadrant of Washington (Fig. 1). Geologic maps of these quadrangles have been compiled by Washington Division of Geology and Earth Resources (DGER) geologists and are the principal data sources for the new 1:250,000-scale geologic map of the northeast quadrant of Washington, which is in preparation. Fourteen of these quadrangles will be released as DGER open-file reports (listed below); the Chelan and Wenatchee quadrangles have not been open-filed because they have been published by the U.S. Geological Survey (USGS) (Tabor and others, 1982, 1987).

Literature review and preliminary compilation of the Spokane quadrangle began in 1988. Between 1988 and 1990, reconnaissance geologic mapping was performed by the DGER staff in the western three-fourths of the map area where previously published geologic maps have been generally limited to a scale of 1:125,000 or smaller. While DGER mapping has been reconnaissance in nature, this new information has added to the understanding of the geology of the Spokane quadrangle. However, much more geologic mapping is needed in the quadrangle to further define, refine, and describe units and to understand the complex geology of the area. Figure 2 shows sources of geologic map data used for compilation of the Spokane quadrangle map.

Age assignments of geologic units in the Spokane 1:100,000-scale quadrangle were made following the flow chart in Figure 3. The geologic time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador, 1985) was used, with slight modifications of the Eocene-Oligocene and Pliocene-Pleistocene boundaries (Armentrout and others, 1983; Prothero and Armentrout, 1985; Montanari and others, 1985; Aguirre and Pasini, 1985). All known published radiometric ages from the Spokane quadrangle are listed in Table 1, which follows the list of cited references.

Modal analyses and the International Union of Geological Sciences rock classification (Streckeisen, 1973) were used to assign plutonic rock names. Whole-rock geochemical data and the total alkali-silica (TAS) diagram (Zanettin, 1984) were the basis for assigning names to volcanic rocks. The term metamorphic rocks applies to rocks of amphibolite grade or higher. Rocks of lower grade than greenschist are included in sedimentary, volcanic, or intrusive rock packages; greenschist grade rocks are designated as metasedimentary or metavolcanic rocks.

A mixture of formal, informal, and unnamed geologic units is shown on the map. Unit symbols provide information about the age, lithology, and name (if any) of the units: upper-case letters indicate age; lower-case letters indicate lithology; and subscripts identify named units. Example: the Fan Lake granodiorite is a Cretaceous intrusive granodiorite, and it is shown with the symbol Kigd<sub>r</sub>.

### DGER Northeast Quadrant Open-file Reports

Bunning, B. B., compiler, 1990, Geologic map of the east half of the Twisp, 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-9, 52 p., 1 pl.

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

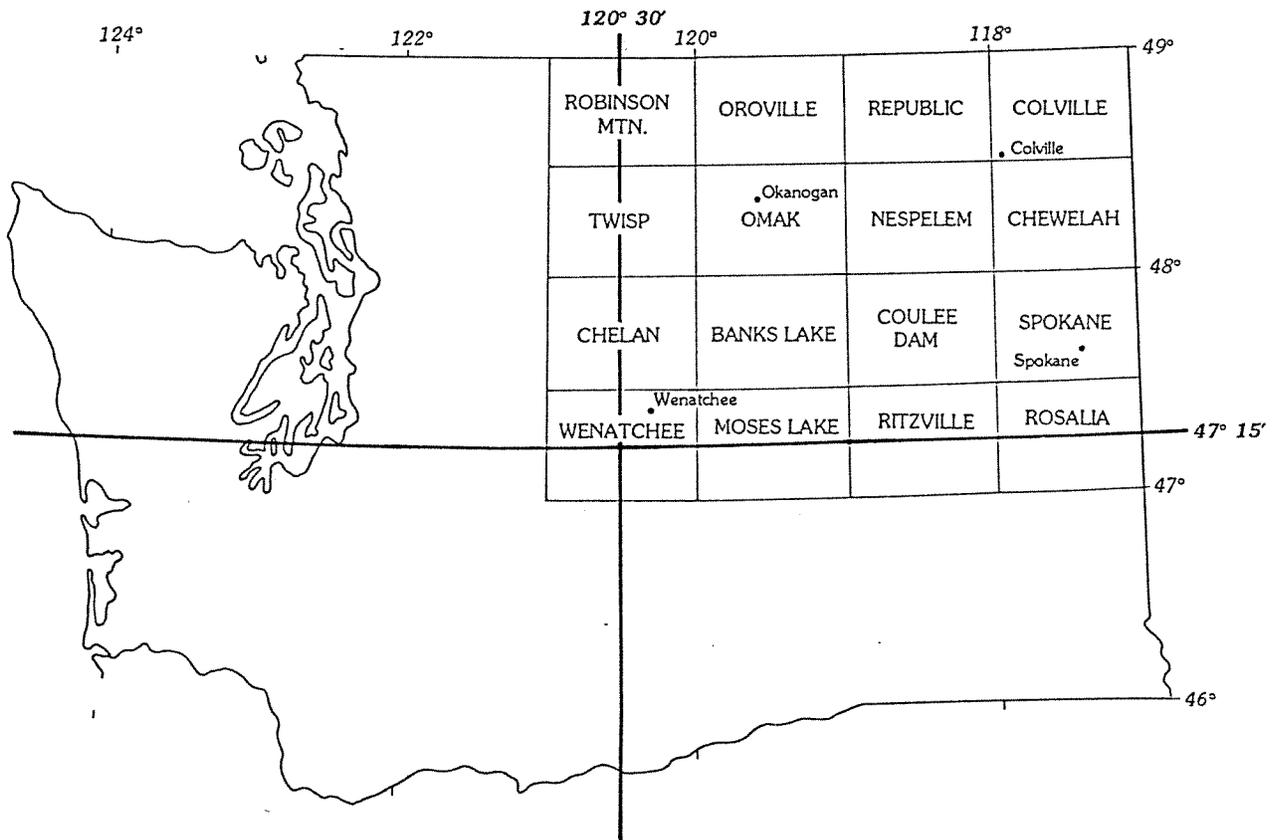


Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Explanation for Figure 2, facing page

1. Griggs, 1966, 1 sheet, scale 1:125,000.
2. Griggs, 1973, 1 sheet, scale 1:250,000.
3. Hosterman, 1969, 1 plate, scale 1:24,000.
4. Kiver and others, 1979, 1 sheet, scale 1:250,000.
5. Page, 1942, plate 32, scale 1:2,400.
6. Rhodes and others, 1989, figure 2, scale 1:158,000.
7. Swanson and others, 1979, plate 1, scale 1:250,000.
8. Weis, 1968, 1 sheet, scale 1:62,500.
9. Weissenborn and Weis, 1976, 1 sheet, scale 1:62,500.

DGER, unpublished reconnaissance geologic mapping

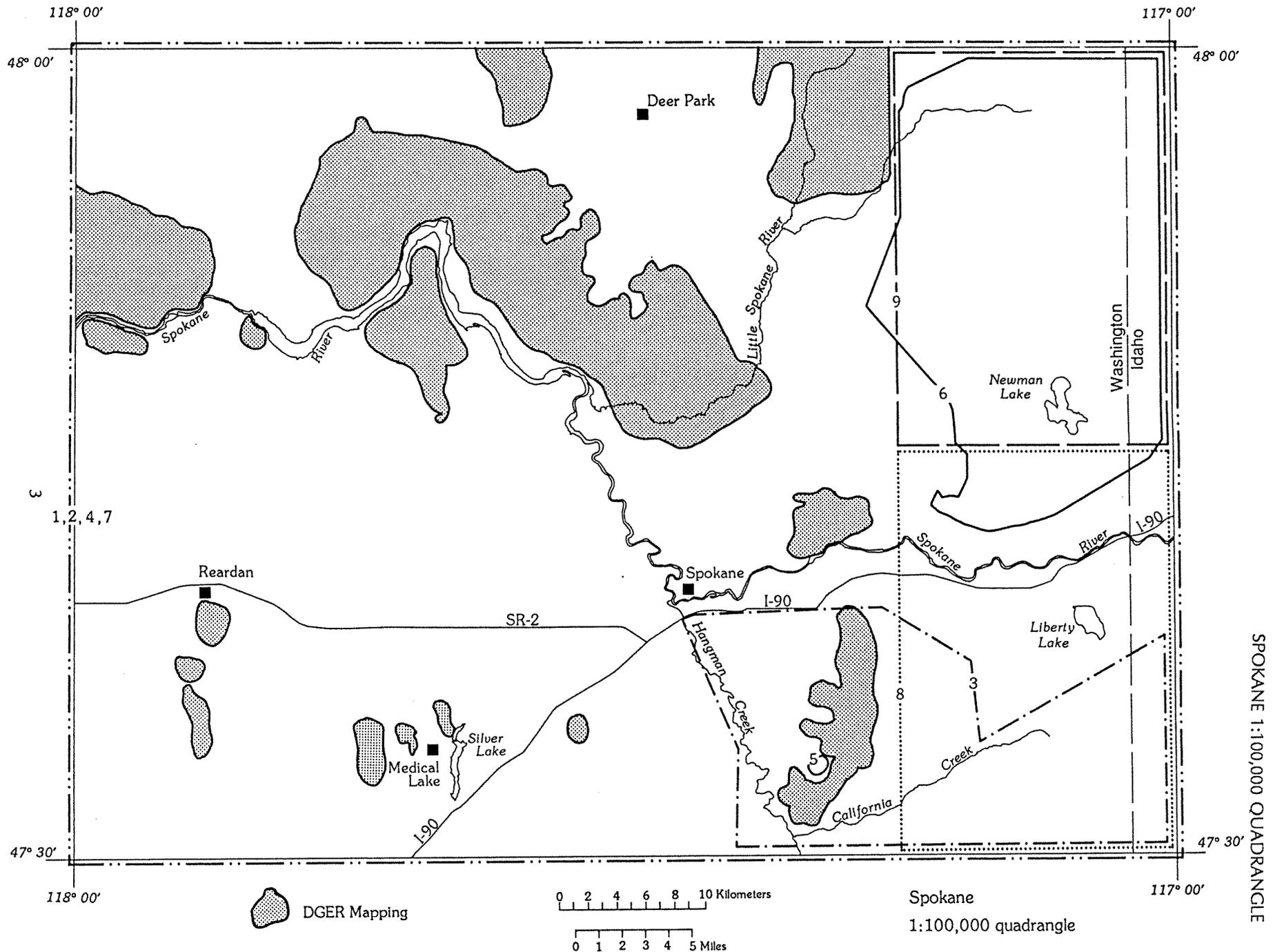


Figure 2. Sources of geologic mapping used to compile the Spokane 1:100,000-scale quadrangle geologic map.

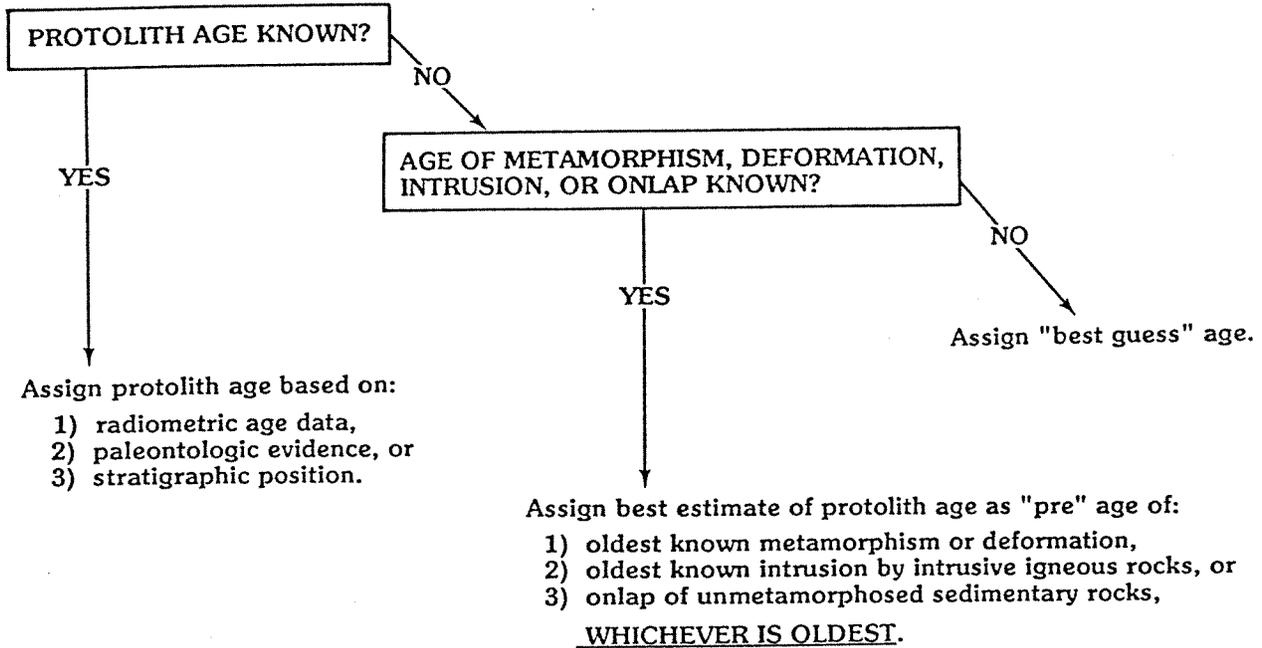


Figure 3. Flow chart for age assignment of geologic units, Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description includes information on how the age of the unit was determined.

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

Gulick, C. W.; Korosec, M. A., compilers, 1990, Geologic map of the Banks Lake 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-6, 20 p., 1 pl.

Gulick, C. W.; Korosec, M. A., compilers, 1990, Geologic map of the Omak 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-12, 52 p., 1 pl.

Joseph, N. L., compiler, 1990, Geologic map of the Colville 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-13, 78 p., 1 pl.

Joseph, N. L., compiler, 1990, Geologic map of the Nespelem 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-16, 47 p., 1 pl.

Joseph, N. L., compiler, 1990, Geologic map of the Spokane 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-17, 29 p., 1 pl.

## SPOKANE 1:100,000 QUADRANGLE

- Stoffel, K. L., compiler, 1990, Geologic map of the Oroville 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-11, 58 p., 1 pl.
- Stoffel, K. L., compiler, 1990, Geologic map of the Republic 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-10, 62 p., 1 pl.
- Stoffel, K. L.; McGroder, M. F., compilers, 1990, Geologic map of the Robinson Mtn. 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-5, 39 p., 1 pl.
- Waggoner, S. Z., compiler, 1990, Geologic map of the Chewelah 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-14, 63 p., 1 pl.
- Waggoner, S. Z., compiler, 1990, Geologic map of the Coulee Dam 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-15, 40 p., 1 pl.
- Waggoner, S. Z., compiler, 1990, Geologic map of the Rosalia 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-7, 20 p., 1 pl.

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### GENERAL GEOLOGIC SETTING

The Spokane 1:100,000-scale quadrangle can be divided into three geologic blocks defined by the presence of Precambrian rocks of different sedimentary facies and metamorphic grade. From west to east, these are: (1) Precambrian Y Deer Trail Group intruded by generally undeformed Cretaceous intrusive rocks; (2) Precambrian Y Belt Supergroup rocks intruded by undeformed and foliated and lineated Eocene and Cretaceous plutons; and (3) high-grade metamorphic rocks of the Spokane dome of the Priest River metamorphic core complex, which are intruded by deformed and massive Cretaceous and Eocene muscovite-biotite-bearing intrusive rocks. The exact boundaries of these blocks and the nature of the contacts between them are poorly understood. The contact between blocks 1 and 2 is likely a fault; in the Chewelah 1:100,000-scale quadrangle, the west-dipping, low-angle Jumpoff Joe fault juxtaposes the Deer Trail Group and the Belt Supergroup. The contact between blocks 2 and 3 is also probably a fault that places Precambrian rocks of greenschist facies against rocks of amphibolite grade; alaskite and pegmatite sills and dikes are present near this boundary.

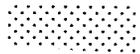
Overlying these blocks are younger Tertiary and Quaternary rocks and sediments. Flows of the Miocene Columbia River Basalt Group and associated sedimentary rocks are present below a elevation of 760 m. Stratified boulders, sand, and gravel below an elevation of 800 m are generally the result of catastrophic outburst floods from Pleistocene glacier-dammed lakes. Minor amounts of glacial drift and till are present in the northern half of the map area. Holocene surficial deposits lie on virtually all the older rock units.

#### Explanation for Figure 4, facing page

Q	Quaternary rocks
Mv	Miocene Columbia River Basalt Group
CY	Cambrian or Precambrian Y metasedimentary rocks
Y <sub>dt</sub>	Precambrian Y Deer Trail Group
Y <sub>b</sub>	Precambrian Y Belt Supergroup
Ei	Eocene hypabyssal dikes
Eia	Eocene hornblende-biotite quartz monzonite
Eiat	Eocene muscovite-biotite granite
TKiaa	Tertiary-Cretaceous alaskite
TKia	Tertiary-Cretaceous biotite-bearing intrusive rocks
Kia	Cretaceous undeformed hornblende-biotite granodiorite
Kiat	Cretaceous muscovite-biotite granite
Kog	Cretaceous orthogneiss
Kog <sub>n</sub>	Cretaceous Newman Lake Gneiss
PCm	Precambrian metamorphic rocks



Weak to strong foliation



Lineated rocks (generally N. 70° E. to S. 70° W.)



Brittlely deformed alaskite-cemented breccia



Thermally upgraded metasedimentary rocks with no apparent structural fabric



## DESCRIPTION OF MAP UNITS

### Sedimentary and Volcanic Rocks

#### Quaternary Rocks

##### Nonglacial Deposits

###### Qa

Alluvium (Holocene)--Stream deposits primarily of silt, sand, and gravel in floodplains, terraces, and valley bottoms. Locally the unit includes lacustrine, paludal, and eolian deposits in depressions.

###### Qp

Peat deposits (Holocene)--Brown to yellow-brown fibrous peat, sedimentary peat, and muck present in flatlands near lakes. Peat is locally mixed with sand and silt and mixed or interbedded with one or two medium to thin beds of volcanic ash. The peat was mapped by Rigg (1958) at the southern end of Liberty Lake, the northwestern edge of Newman Lake, in Saltese Flat, the south end of Bailey Lake, and around Little Trout Lake. Only larger deposits are shown on Plate I.

###### Qd

Dunes (Holocene-Pleistocene)--Active and stabilized dunes of predominantly fine to medium sand; mostly composed of quartz and basalt grains reworked from older sedimentary rocks (Kiver and others, 1979).

###### Qls

Landslide deposits (Pleistocene)--Unstratified and poorly sorted clay, silt, sand, and gravel deposited by rotational and translational slides and flows (Kiver and others, 1979). Slides are generally restricted to the sides of the "prairies and bluffs" and are as much as several kilometers in length, and some are more than 1.5 km across. Some slides contain individual blocks of basalt that are nearly 8 m in diameter. Well logs show that the Latah Formation generally underlies the slides. Most slides are covered with or partially buried by Pleistocene flood deposits (Qfg) and appear to be late Pleistocene in age. A few slides, such as along Deep Creek, have been active in historic time (Griggs, 1976).

###### Ql

Loess (Pleistocene)--Light- to medium-brown, unstratified, eolian silt, clay, sand, and ash. The unit contains 5 percent sand, 60 percent silt, and 35 percent clay. Clay is mostly montmorillonite and illite in a ratio of 3:1; it also contains minor kaolinite. The sand and silt fraction is composed of angular quartz grains and lesser amounts of feldspar and muscovite. Heavy minerals include limonite, monazite, tourmaline, hornblende, garnet, epidote, and apatite. The loess mantles the Columbia River basalt and is most common on the tops of low hills and plateaus where erosion by water has been minimal. The loess is as thick as 23 m in Spokane County; it averages 6 m thick south of the Spokane River and thins to the north where there is more topographic relief (Hosterman, 1969).

Evidence for several episodes of loess deposition comes from exposures in the Washtucna area in the Connell 1:100,000-scale quadrangle. Near Washtucna, buried paleosols with negative magnetic polarity are interstratified with loess that is interbedded with flood gravel. The polarity indicates the loess there was deposited prior to 790 ka (McDonald and Busacca, 1988). Near Washtucna, the presence of younger loess is indicated by an interbed of set C tephra from Mount St. Helens dated at 36 ka (McDonald and Busacca, 1988) and loess blanketed by 7 ka Mount Mazama tephra (Foley, 1982).

**Glacial and Periglacial Deposits****Qgl**

Glaciolacustrine deposits (Pleistocene)--Light-gray, friable, poorly bedded, fine sand, silt, and clay deposited in pre-late Wisconsin Lake Spokane (Kiver and others, 1989; Weissenborn and Weis, 1976; Weis, 1968). This unit, as mapped, includes some Holocene deposits along Liberty Creek and Saltese Flat (Weis, 1968).

**Qgd**

Glacial drift (Pleistocene)--Till, outwash, and ice-contact stratified deposits in moraines, till plains, and meltwater channels and terraces deposited during the last glacial advance. The unit is generally restricted to the Chamokane Creek valley (Kiver and others, 1979).

**Qfg**

Flood deposits, gravel (Pleistocene)--Poorly sorted, stratified mixture of boulders, cobbles, gravel, and sand resulting from multiple episodes of catastrophic outbursts from glacier-dammed lakes, such as glacial Lake Missoula. The Spokane Valley was one of the main channelways for outburst flood waters from glacial Lake Missoula which inundated much of the present Clark Fork River drainage in Montana and Idaho. Floods flowed from the Spokane Valley through the Cheney Palouse Scabland tract to the Columbia Basin. Flood waters also traveled north of Mount Spokane through the Hillyard trough to the Little Spokane and Spokane Rivers (Molenaar, 1988). The upper elevation of effective erosion by flood water in the Spokane Valley was more than 800 m near Dishman (Kiver and Stradling, 1989).

Radiocarbon dating and paleomagnetic measurements indicate that flood deposits are late Wisconsin and pre-late Wisconsin in age. Examination of graded couplets in flood deposits in the Spokane quadrangle and elsewhere led Waitt (1985) to the interpretation that in excess of 40 flood episodes took place during the late Wisconsin. Waitt (1985) has estimated that glacial Lake Missoula existed for 2,000 to 2,500 years, between 15,300 and 12,700 yr B.P. A giant ripple field near Airway Heights contains Mount St. Helens ash in the troughs of dunes overlain by flood gravel, indicating that one or more floods occurred at about 13,000 ka (Kiver and others, 1989). Tephra correlation and accelerated radiocarbon dating near Washtucna show that some of the pre-late Wisconsin floods occurred at 40 ka (McDonald and Busacca, 1988, 1989). On the basis of paleomagnetic measurements on interbedded loess, McDonald and Busacca (1989) suggest that more than five episodes of flooding occurred prior to 790 ka in the Cheney Palouse Scabland tract.

In the Acme gravel pit in the Spokane Valley, flood deposits consist of cobble- to boulder-size (to 3 m long) clasts; large-scale, west-dipping foreset beds are 5 to 6 m thick and are overlain by a lag deposit of horizontally bedded sand and gravel (Kiver and Stradling, 1989). In a pit near Barker Road in the Spokane Valley, rhythmic bedding from lower energy flood waters in a relatively protected site are exposed. Each set of rhythmites consists of coarse, poorly bedded, pebbly sand disconformably overlain by well-bedded, fine sand. Pebbles and rip-up clasts of Pleistocene lake deposits and Miocene Latah Formation are present near the base of each coarse sand unit (Kiver and Stradling, 1989).

**Qglf**

Glaciolacustrine and flood deposits (Pleistocene)--Glaciolacustrine deposits containing silt and clay couplets interbedded with coarser clastic deposits of catastrophic floods. The deposits are generally restricted to Latah Creek and the lower Spokane River. Along Latah Creek, 1.5- to 5-m-thick units of cyclic, upward-fining and -thinning sequences containing coarse clastic sediments are interbedded with 2-cm- to 20-cm-thick beds of varve-like, fine-laminated clay and silt couplets. The sand- to granule-size fragments in the coarse-grained material are chiefly composed of metamorphic rocks and lesser amounts of basalt, plutonic rocks, and quartz grains; pebble- to boulder-size clasts (to 106 cm in diameter) are similar in composition to the sand- and

granule-size fragments and include clasts of semiconsolidated material, some of which is recognizable as Latah Formation. Unconformably overlying and incised into the cyclic sediments is a 7- to 9-m-thick, cut-and-fill channel filled with coarse gravel. Generally above the gravel are cyclic, upward-fining and -thinning, rhythmically bedded, buff-colored, sand and silt-rich units which are similar to the Touchet beds in southern Washington. The sequence is overlain by Mazama ash that is radiocarbon dated at 6,700 ka (Rigby, 1982).

Rigby (1982) concluded that the sediments below the unconformity are turbidites generated by catastrophic floods from glacial Lake Missoula and deposited into a lake that was present in the Latah Creek area from 37 ka to 18 ka. Sediments above the unconformity are thought by Rigby (1982) to be slackwater deposits derived from pulses of catastrophic floodwaters surging upstream from the Little Spokane River between approximately 17 ka and 13 ka.

### Pliocene-Miocene Sedimentary and Volcanic Rocks

#### P<sub>t</sub>Mcg

Conglomerate (Pliocene-Miocene)--Well-indurated, manganese- and iron-cemented conglomerate that is present 14 km north of Wellpinit. The conglomerate overlies horizontal beds of arkosic sand that also contain manganese and iron cements. The conglomerate contains as much as 0.023 percent U<sub>2</sub>O<sub>3</sub> in the matrix (Ingersoll and others, 1980). Directly to the north in the Chewelah 1:100,000-scale quadrangle, the unit overlies the rocks of the Columbia River Basalt Group (F. K. Miller, USGS, oral commun., 1988 in Waggoner, 1990).

### Columbia River Basalt Group

#### AAV<sub>wp</sub>

Wanapum Basalt, Priest Rapids Member (middle Miocene)--Fine- to coarse-grained, aphyric basalt flows of reversed magnetic polarity (Swanson and others, 1979). They generally contain fine phenocrysts of plagioclase and olivine. The basalt is of the Rosalia chemical type and has higher titanium and lower magnesium and chromium contents than other flows of the Wanapum Basalt (Wright and others, 1989). The unit overlies and is commonly invasive into the lakebed sediments of the Latah Formation or overlies the Grande Ronde Basalt N<sub>2</sub> unit. Flows of the Priest Rapids Member are thought to have been extruded between 15.3 and 14.5 Ma (Reidel and Fecht, 1987). This unit includes the "Rim rock" flows of Pardee and Bryan (1926).

#### AAV<sub>gN2</sub>

Grande Ronde Basalt, magnetostratigraphic unit N<sub>2</sub> (middle Miocene)--Upper flows of the Grande Ronde Basalt, of normal magnetic polarity. The basalt is aphyric to sparsely phyric and contains minor amounts of small plagioclase laths. The flows, which are commonly pillowed, are as much as 50 m thick, but are generally 15 to 25 m thick. Flows of the Grande Ronde Basalt are thought to have been extruded between 15.6 and 16.5 Ma (Reidel and Fecht, 1987), and they overlie pre-Tertiary rock in the Spokane quadrangle. The Grande Ronde Basalt makes up the "Valley flows" of Pardee and Bryan (1926). The base of the basalt reportedly was penetrated at about 130 m below the valley floor in the well at the Davenport Hotel in downtown Spokane (Griggs, 1976).

Ac<sub>1</sub>

Latah Formation (Miocene)--Gray to tan to yellow-orange siltstone, claystone, and minor sandstone named by Pardee and Bryan (1926) for lacustrine and fluvial deposits along Latah Creek. Kirkham and Johnson (1929) suggested extending the formation name west to Grand Coulee; however, Griggs (1976) has suggested that the name Latah be restricted to the drainage of the Spokane River, as originally intended by Pardee and Bryan (1926).

Pardee and Bryan (1926) included in the Latah Formation both the sediments interbedded with the Miocene Columbia River Basalt Group and the 305 meters of sediments below the base of the basalt in the Latah-Texas well near the mouth of Latah Creek. They also include the 73 meters of sediment below the lowest basalt in the well at the Davenport Hotel (Pardee and Bryan, 1926). A large part of the exposure of the Latah Formation is located between flows of the Grande Ronde Basalt and the Priest Rapids Member.

Floral assemblages in the Latah Formation indicate a Miocene age (Knowlton, 1926). More than 95 forms make up the floras in the Spokane and Coeur d'Alene areas. These include well-preserved species of Ginkgo, Sequoia, Taxodium, Populus, Castanea, Quercus, Ulmus, and Acer.

### Metasedimentary Rocks

#### **Cambrian or Precambrian Y Metasedimentary Rocks**

€Ymm

Metasedimentary rocks, undivided (Cambrian or Precambrian Y)--Medium- to thick-bedded, fine-grained, muscovite-bearing quartzite to silty quartzite that contains minor chlorite, and thin-bedded, light- to dark-gray, quartz-rich phyllite and muscovite schist that also includes minor biotite. These rocks are contiguous with the unit of metasedimentary rocks of uncertain age mapped by Becraft and Weis (1963) to the west on the Turtle Lake 15' quadrangle (Coulee Dam 1:100,000-scale quadrangle). The rocks mapped by Becraft and Weis (1963) appear to be thicker than those generally exposed in the lower Paleozoic sequence in this part of northeastern Washington, suggesting a Precambrian age. However, in the Coulee Dam 1:100,000-scale quadrangle, the unit contains a thick section of calcite-bearing marbles; carbonate rock in the Precambrian section is generally dolomitic. Because of the uncertainty in the age of the rock and the lithologies present, this unit is probably Cambrian or Middle Proterozoic (Precambrian Y) in age.

€Yq

Quartzite near Edwall (Cambrian or Precambrian Y)--Medium- to thick-bedded, white to light-gray, fine-grained, vitreous quartzite that contains authigenic feldspar. The quartzite is interbedded with medium- to thin-bedded buff and light-green siltite. This poorly exposed unit is most probably Precambrian Y in age; however, it could be part of the Cambrian-Precambrian Z Addy Quartzite.

#### **Precambrian Y Metasedimentary Rocks**

##### **Deer Trail Group**

Yq<sub>bh</sub>

Buffalo Hump Formation (Precambrian Y)--White to light-gray, thick-bedded quartzite, pebbly quartzite, and medium- to dark-gray, thin-bedded siltite. Pebble-bearing quartzite is present on Fancher Butte and Booth Hill. The pebbles are 3- to 6-mm-long, white and blue, opaque, rounded to subrounded quartz clasts that

define bedding in the quartzite. Larger pebbles, as much as 25 mm long, are composed of purplish and pinkish quartzite and constitute as much as 50 percent of the pebbly quartzite. On the western hill of Fancher Butte medium- to dark-gray, thin-bedded, thin- to very thin laminated siltite and minor quartzite are present as float. Quartzite on Fancher Butte and Booth Hill could be the Addy Quartzite, but it is most likely part of the Buffalo Hump Formation. The thickness of this unit in the Spokane quadrangle can not be accurately estimated because of poor exposure and probable structural complexities.

Yq

Quartzite (Precambrian Y)--White to light-gray, medium- to thick-bedded, medium- to coarse-grained, grain-supported quartzite interbedded with medium- to thin-bedded muscovite-biotite schist. The unit is exposed as isolated outcrops on ridge tops and in small drainages in the northwest part of the map area. This quartzite locally contains minor disseminated pyrite, muscovite, and chlorite. The unit is most likely part of the Buffalo Hump or Togo Formations of the Deer Trail Group, but it could be part of the Cambrian-Precambrian Z Addy Quartzite. Outcrops of the quartzite are too scattered to permit accurate thickness estimates.

Ymm<sub>m</sub>

McHale Slate (Precambrian Y)--Medium- to dark-gray argillite interlaminated with tan, light-gray and white siltite to quartzite laminae that crops out on Magnison Butte and Hanning Butte. Bedding thickness ranges from laminations on the sub-millimeter scale to fining-upward couplets as thick as 30 mm. Even parallel laminations and soft-sediment deformation are common. The McHale Slate in the Spokane quadrangle appears to be similar to the lower 100 to 120 m of the formation as described by Miller and Whipple (1989) in the Chelwelah 1:100,000-scale quadrangle. The unit exhibits weak cleavage.

### **Belt Supergroup**

Yms<sub>w</sub>

Wallace Formation (Precambrian Y)--Calc-silicate, hornfels, calcite- and epidote-cemented quartzite, gray fissile argillite, phyllite, mica schist, and quartz-plagioclase-biotite gneiss that is present near Medical Lake. Original lithologies were probably similar to those of rocks mapped as the lower Wallace Formation by Griggs (1973) in the Rosalia 1:100,000-scale quadrangle. There, the upper part of the unit consists of couplets of black argillite and light-gray to greenish-gray siltite, and medium- to thick-bedded carbonate-bearing quartzite.

Yms<sub>r</sub>

Ravalli Group (Precambrian Y)--Quartzite, silty quartzite, schist, and siltite present south and west of Spokane (Griggs, 1973). The unit is dominantly vitreous, medium- to coarse-grained, white to light-gray, medium- to thick-bedded quartzite and interbeds of quartz-biotite-muscovite schist. The quartzite contains as much as 10 percent authigenic feldspar. The unit is generally thermally upgraded south of Spokane and near Cheney; greenschist-facies rocks are present immediately west of State Route 195. The contact relation with older gneiss is undefined. On Krell Hill, the contact of the heterogeneous metamorphic rocks (PChm) with the Ravalli Group is obliterated by the intrusion of a body of alaskite (TKiaa). This contact, however, is likely a fault, as rocks of different metamorphic grade and probable age are in juxtaposition. Outcrops of the quartzite abruptly terminate at the drainage south of Browns Mountain, suggesting a possible structural contact with the higher grade rocks there. The maximum thickness of the unit south of Spokane is 1,200 m.

Intrusive Rocks

Eida +++++

Hypabyssal dikes--Light- to dark-gray hypabyssal, porphyritic dikes generally in the northern and western part of the map area. The fine-grained matrix is composed of feldspar, quartz, hornblende, and biotite. Phenocrysts include hornblende (as much as 0.5 cm long), subhedral biotite, plagioclase (as much as 1 cm long), and minor K-feldspar (Miller, 1974c). A dike that has a similar mineralogy on the Chewelah 1:100,000-scale quadrangle northeast of Elk yielded a K-Ar age of  $47.3 \pm 1.6$  Ma on hornblende and  $46.8 \pm 1.4$  Ma on biotite (Miller, 1974c).

Eigd,

Biotite-hornblende-bearing intrusive rock near Tumtum (Eocene?)--Lineated (nearly east-west lineation) and foliated, medium- to coarse-grained, biotite-hornblende monzodiorite to granodiorite. The unit is present west of Tumtum and near Medical Lake. West of Tumtum the unit is characterized by: aligned, euhedral, black hornblende; pink and white poikilitic K-feldspar phenocrysts aligned subparallel to the hornblende; and abundant wispy mafic xenoliths. The biotite to hornblende ratio is 1:2; hornblende commonly has pyroxene cores. The rock contains 1 to 2 percent titanite.

Near Medical Lake the unit includes leucocratic, medium-grained, equigranular to porphyritic, foliated and lineated diorite to granodiorite that has macroscopic mineralogy and fabric similar to the rock near Tumtum. The rock at Medical Lake contains subhedral quartz that is interstitial to feldspar, anhedral plagioclase, white euhedral to subhedral K-feldspar, subhedral black biotite which is associated with pyrite, and hornblende as euhedral phenocrysts and/or in clots with pyroxene cores. The rock contains accessory magnetite and abundant titanite. Schlieren is locally present.

The unit near Tumtum is thought by F. K. Miller (USGS, oral commun., 1989) to be similar to the border phase of the Silver Point Quartz Monzonite in the Chewelah 1:100,000-scale quadrangle. North of the Spokane River, the unit is cut by brittlely deformed alaskite pegmatite dikes which cut across the fabric in the monzodiorite and cement a breccia that contains fragments of a deformed monzodiorite that is well exposed in NE1/4 sec. 16, T. 27 N., R. 40 E. The contact of the intrusive rock near Tumtum with the Silver Point Quartz Monzonite is generally gradational. South of the Spokane River, the unit is probably in fault contact with the biotite-bearing intrusive rock near Four Mound Prairie.

Eiqm,

Silver Point Quartz Monzonite (Eocene)--Leucocratic (color index 14-21), coarse-grained, porphyritic hornblende-biotite quartz monzonite that is present on Scoop Mountain. The formation was named by Miller and Clark (1975) for exposures near Silver Point on Loon Lake in the Chewelah 1:100,000-scale quadrangle. The groundmass has a characteristic bimodal texture and consists of K-feldspar, quartz, hornblende, biotite, and plagioclase; K-feldspar and quartz are coarser grained than the other constituents in the matrix. Biotite is more common in the fine-grained phase of the groundmass than in the coarse-grained part. Microperthitic orthoclase phenocrysts are 6 to 37 mm in length and make up 1 to 5 percent of the rock. Quartz is interstitial to other minerals. Hornblende is subhedral to euhedral, has a long dimension as much as 10 mm, and is associated with biotite. The hornblende to biotite ratio is consistently .75:1. Titanite is the most common accessory mineral, followed by magnetite, apatite, zircon, and rare allanite (Miller and Clark, 1975). The pluton is generally massive, but it is foliated in Rail Canyon parallel to the contact with the biotite-bearing intrusive rock in Corkscrew Canyon (TKia<sub>2</sub>) and foliated near the contact with the biotite-hornblende-bearing intrusive rock near Tumtum. The Silver Point unit is cut by north-northwest-trending, biotite-chlorite-silica-bearing zones that display cataclasis (Miller and Clark, 1975). Two samples from the localities in the Chewelah 1:100,000-scale quadrangle returned whole-rock Rb-Sr ages of  $39 \pm 4$  Ma and  $46 \pm 2$  Ma (Armstrong and others, 1987). Recalculated K-Ar ages on rocks from the Chewelah 1:100,000-scale

quadrangle are 51 Ma on biotite and 62 Ma on hornblende (Miller and Clark, 1975). The initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of  $0.7063 \pm 0.0002$  from the pluton was the lowest found by Armstrong and others (1987) after studying several plutons in the area. Armstrong and others (1987) suggest that the low initial isotope ratios confirm that the pluton has an Eocene age and not a reset Cretaceous age.

Eiat,

Mount Rathdrum granite (Rhodes and Hyndman, 1984)--Massive to very weakly foliated, leucocratic, fine- to medium-grained, equigranular, muscovite-biotite quartz monzonite to granite that forms small plutons and dikes that sharply cut the foliation of the older mylonitic rocks. The unit was named by Rhodes and Hyndman (1984) for exposures on Mount Rathdrum in Idaho and is present in the Spokane quadrangle near Hauser and Newman Lakes. The granite contains quartz, K-feldspar, plagioclase containing myrmekitic intergrowths, biotite, and minor muscovite (Weissenborn and Weis, 1976). The bodies are intruded along the axis of the south-plunging Spokane dome of the Priest River complex. Larger bodies of this intrusive unit are generally massive, whereas dikes commonly have structural fabric. Dikes of Mount Rathdrum granite commonly dip  $10^\circ$  to  $15^\circ$  more steeply to the west than mylonitic foliation of the enclosing metamorphic rock. Partings in the dikes display moderate to strong slickenside-like lineation parallel to the N.  $70^\circ$  E. lineation in the mylonitic rocks of the Hauser Lake Gneiss (Rhodes and Hyndman, 1984).

Preliminary discordant U-Pb geochronology from undeformed samples suggest a minimum early Eocene (52 Ma) age for the pluton (Bickford and others, 1985). Rhodes and Hyndman (1984) suggest that the granite is a late synkinematic rock intruded during mylonitic deformation associated with the Priest River complex, and thus it experienced only a small increment of the total strain. Dikes and sills which cooled more rapidly exhibit more deformation and likely cooled before the last movement along the mylonite zone (Rhodes and others, 1989).

TKiaa

Alaskite, pegmatite, and aplite (Tertiary-Cretaceous)--Discontinuous sill- and dike-like bodies of alaskite, pegmatite, aplite, and fine- to coarse-grained quartz monzonite. This unit consists of quartz, K-feldspar, plagioclase, muscovite, and minor red subhedral garnet; it locally contains minor biotite.

Leucocratic, white to tan alaskite intrudes and is gradational with the biotite-muscovite-bearing Mount Spokane granite. This alaskite consists of medium- to coarse-grained quartz, megacrystic K-feldspar, plagioclase, and muscovite; biotite is absent except near intrusive contacts. Accessory minerals include garnet, apatite, zircon, and monazite. Pegmatite and graphic intergrowths are common (Weissenborn and Weis, 1976; Weis, 1968). As mapped, the alaskite unit locally includes outcrops of the Mount Spokane granite. Autunite and meta-autunite are present as fracture coatings and solid masses of crystals on alaskite on the west side of Mount Kit Carson. A total of 90,000 lb of  $\text{U}_3\text{O}_8$  were produced from nine properties; most of the ore came from the Daybreak mine (Weissenborn and Weis, 1976).

The unit includes alaskite, pegmatite, and quartz monzonite that intrudes the heterogeneous metamorphic rocks (PChm) and metasedimentary rocks of the Ravalli Group (Yms) on Krell Ridge. Alaskite pegmatite with K-feldspar megacrysts (to 15 cm in length) generally has no fabric on Krell Hill; however, biotite, where present, is commonly clotted. The alaskite is intruded parallel to subparallel to the foliation in quartzite and gneiss of the heterogeneous metamorphic rocks, with local stoping. On Krell Ridge, the body forms small resistant knobs and is present along the contact, a probable fault, between the high-grade metamorphic rocks and the metasedimentary rocks of the Ravalli Group.

Brittly deformed alaskite cements breccia and stopes intrusive rocks on the east side of Chamokane Creek from the north border of the map area to near the Spokane River. In NE1/4 sec. 16, T. 27 N., R. 40 E., at the petroglyph site, the brittly deformed alaskite is well exposed, cementing a breccia of and assimilating the foliated and lineated orthogneiss near Tumtum, which is of probable Eocene age. Thin (0.1-1 m), light-colored bands of mylonite that cut the Newman Lake Gneiss near the contact with the Mount Spokane granite on Beacon Hill probably had an alaskite parent.

Rb-Sr ages of alaskite from the Mount Spokane area range from 40 to 159 Ma (Armstrong and others, 1987; Table 1).

## TKia

Biotite-bearing intrusive rock (Tertiary-Cretaceous)--Scattered bodies of undeformed, leucocratic, coarse-grained, equigranular to porphyritic, biotite granite to granodiorite at several localities in the Spokane quadrangle. Some of these bodies are proximal to deformed plutons but are not themselves deformed, suggesting that they may be Eocene in age or not in the zone affected by mylonitization.

Near Griffith Springs, south of the Little Spokane River, the unit includes equigranular biotite granite to granodiorite. This body contains 20 to 30 percent white to lavender, anhedral quartz; 10 to 15 percent subhedral, interstitial black biotite; white K-feldspar; and plagioclase. The intrusive rock is cut by garnet-bearing alaskite dikes, which are, in turn, cut by near-vertical lamprophyre dikes. Minor chlorite and epidote are present on fractures.

Near Milan, leucocratic, equigranular, coarse-grained, biotite quartz monzonite to granite is present and is cut by alaskite pegmatite dikes. The unit also includes coarse-grained, highly weathered, biotite granite containing white K-feldspar phenocrysts that crops out in the valley bottoms near Hangman Valley.

TKia<sub>c</sub>

Biotite-bearing intrusive rock in Corkscrew Canyon (Tertiary-Cretaceous)--Coarse-grained, equigranular to porphyritic, biotite quartz monzonite to granite east of Chamokane Creek. Biotite is anhedral to clotted; lavender-gray quartz is anhedral; and K-feldspar phenocrysts are poikilitic. The weathered intrusive rock is cut by brittlely deformed alaskite, pegmatite, and aplite dikes, which also locally cement breccia made up of blocks of the unit. The biotite-bearing intrusive rock is foliated along the contact with the Silver Point Quartz Monzonite and the orthogneiss near Tumtum. These rocks are possibly part of the body of leucocratic intrusive rock exposed south of the Spokane River (TKia<sub>r</sub>).

TKia<sub>mc</sub>

Intrusive rock near Mud Creek (Tertiary-Cretaceous)--Leucocratic, coarse-grained, equigranular, biotite quartz monzonite to granite with trace to 1 percent isolated flakes of muscovite. Quartz is present as light-gray, rounded grains in coarse-grained aggregates and pods. The intrusive rock contains coarse grains and phenocrysts of white, twinned K-feldspar, 3 to 8 percent subhedral black biotite, and 1 percent magnetite as isolated grains. The unit is megascopically similar to the alaskite, pegmatite, and aplite unit, except that the intrusive rock near Mud Creek has relatively increased biotite and decreased muscovite contents. It is possibly a late-stage phase of the muscovite-biotite-bearing intrusive rock near the Little Spokane River.

TKia<sub>r</sub>

Biotite-bearing intrusive rock near Four Mound Prairie (Tertiary-Cretaceous)--Massive to weakly foliated, leucocratic, medium- to coarse-grained, equigranular, biotite granite to quartz monzonite present south of the Spokane River on Four Mound Prairie. As mapped, the unit probably includes more than one body, and it is possibly part of the biotite-bearing intrusive rock in Corkscrew Canyon (TKia<sub>c</sub>) on the north side of the Spokane River. Light-gray quartz is present in clots or aggregates of crystals and is intergrown with K-feldspar. White K-feldspar forms some phenocrysts and clots of phenocrysts. Anhedral to subhedral, black biotite comprises 2 to 7 percent of the rock and generally is interstitial to other minerals. The unit is cut by alaskite pegmatite dikes. Outcrops east of Davis Lake (secs. 5 and 6, T. 26 N., R. 40 E.) are foliated and lineated and contain clotted and stretched quartz grains.

Kia<sub>m</sub>

Intrusive rock near the Midnight mine (Cretaceous)--Leucocratic, medium- to coarse-grained, locally porphyritic quartz monzonite to granite that is present near Round Mountain. Similar rock was named by Becraft and Weis (1963) for exposures in the Coulee Dam 1:100,000-scale quadrangle to the west. The intrusive rock contains 26 to 32 percent K-feldspar, 20 to 42 percent quartz, 26 to 32 percent plagioclase, 1 to 4 percent muscovite, and 0 to 3 percent biotite that is partially replaced by chlorite and muscovite. K-feldspar, followed by quartz and plagioclase, are the dominant phenocrysts. Quartz is anhedral and has a smoky color; subhedral to euhedral plagioclase is twinned. Muscovite is present as inclusions within K-feldspar or as an alteration product of biotite and is associated with chlorite (Kinart, 1980). Accessory minerals include magnetite (to 1%), apatite, fluorite, garnet, zircon, and monazite. Alaskite and quartz porphyry comprise more than 10 percent of the pluton (Castor and others, 1982). The average U<sub>3</sub>O<sub>8</sub> content of this intrusive body is 19 ppm; the range is from 1 to 46 ppm. Strong argillic alteration is locally present (Castor and others, 1982). A U-Pb age of 75 Ma from zircon is reported from the Coulee Dam 1:100,000-scale quadrangle by Ludwig and others (1981). Asmerom and others (1988) reported a Rb-Sr age of 74.7 ± 3 Ma from samples taken in the Coulee Dam 1:100,000-scale quadrangle.

Kigd<sub>f</sub>

Fan Lake granodiorite (Miller, 1974c) (Cretaceous)--Leucocratic, equigranular to porphyritic, medium- to coarse-grained granodiorite to monzogranite that crops out west of the Little Spokane River. The granodiorite was named by Miller (1974c) for exposures near Fan Lake in the Chewelah 1:100,000-scale quadrangle. The granodiorite contains zoned plagioclase of an intermediate composition, quartz, K-feldspar, biotite, and hornblende. Euhedral hornblende phenocrysts are locally as much as 1 cm in length. Accessory minerals include titanite, allanite, zircon, apatite, and opaque minerals. Quartz and K-feldspar are interstitial to plagioclase and mafic minerals. K-Ar ages are 95.1 ± 4 Ma on hornblende and 93.4 ± 2.6 Ma on biotite from the Fan Lake granodiorite in the Chewelah 1:100,000-scale quadrangle (Miller, 1974c).

Kigd<sub>w</sub>

Granodiorite near Wellpinit (Cretaceous)--Leucocratic, massive, medium-grained, biotite-hornblende granodiorite that crops out south of Wellpinit. The granodiorite contains 25 to 30 percent quartz; 35 to 40 percent subhedral, zoned plagioclase (An<sub>40-55</sub>); 10 to 15 percent interstitial K-feldspar; 7 to 15 percent euhedral biotite in laths 2 to 5 mm long; and 7 to 12 percent subhedral to euhedral hornblende. Mafic minerals are partially altered to chlorite. Accessory minerals include titanite, apatite, magnetite, and zircon (Becraft and Weis, 1963). The body is cut by hypabyssal hornblende-biotite dacite dikes and alaskite, pegmatite, and aplite dikes. Three Pb-α ages ranging from 95 ± 10 Ma to 105 ± 10 Ma were obtained by Becraft and Weis (1963) from exposures on the Turtle Lake 15' quadrangle in the northern part of the Coulee Dam 1:100,000-scale quadrangle.

Kiat<sub>o</sub>

Muscovite-biotite-bearing intrusive rock near Otter Creek (Cretaceous)--Leucocratic, coarse-grained, equigranular, foliated, muscovite-biotite quartz monzonite to granite that is present north of Milan. The unit is probably part of the deformed muscovite-biotite quartz monzonite mapped by Miller (1974c) near Eloika Lake in the Newport Number 3 quadrangle in the Chewelah 1:100,000-scale quadrangle (Waggoner, 1990). Biotite is chloritic; muscovite is present both as discrete crystals and intergrown with chlorite and biotite. The micas are commonly wrapped around quartz and feldspar. Sillimanite replacing biotite and cataclasis were observed by Miller (1974c) in thin sections of similar rocks from the Chewelah 1:100,000-scale quadrangle. The two-mica granite is highly weathered and cut by alaskite pegmatite dikes. This intrusive rock is most likely Cretaceous on the basis of its similarities to other muscovite-bearing plutons of probable Cretaceous age in the area.

Kiat<sub>s</sub>

Mount Spokane granite (Cretaceous)--Leucocratic, foliated to massive, medium- to fine-grained biotite-muscovite granite to monzogranite that is present on Mount Spokane. The granite contains quartz, K-feldspar, plagioclase, muscovite, biotite, and accessory apatite, zircon, garnet, and rutile. Biotite and muscovite are shredded; muscovite replaces biotite and replaces feldspar along crystal boundaries. The granite is intruded by and gradational over tens of meters with alaskite, pegmatite, and aplite dikes and sill-like bodies (TKiaa). Muscovite-biotite-bearing granitic rocks on Mount Spokane were mapped as a biotite-muscovite quartz monzonite by Weissenborn and Weis (1976) and later informally called the Mount Spokane granite by Rhodes and others (1989).

The Mount Spokane granite structurally overlies the Newman Lake Gneiss (Rhodes and Hyndman, 1984; Bickford and others, 1985). Various amounts of strain are exhibited at the contact of these two intrusive units. A 2- to 5-m-thick zone containing 0.25- to s-m-thick bands of light-colored mylonite is present on Beacon Hill in lineated (N. 70° E.) Newman Lake Gneiss near the contact with the Mount Spokane granite. The granite on Beacon Hill is foliated and in places contains stretched quartz grains for approximately 15 to 40 m above the mylonite; it then grades upward into generally undeformed rock (DGER, unpublished mapping). Elsewhere to the north, the contact with the Newman Lake Gneiss is represented by a zone of foliated and lineated rock (TKqf and TKqh units of Weissenborn and Weis, 1976). The contact of the Mount Spokane granite with the orthogneiss near Mount Spokane (Kog<sub>s</sub>), which is thought by Rhodes and Hyndman (1984) to be deformed Mount Spokane granite in the mylonitic zone, is gradational over 500 to 1,000 m of structural thickness (Rhodes and Hyndman, 1984). East of Mount Spokane, south-trending, west-dipping foliation is generally present in the granite within 3 to 5 km of the contact with the orthogneiss (Kog<sub>s</sub>); foliation in the Mount Spokane granite fades to the west (Weissenborn and Weis, 1976).

Two samples from the west side of Mount Kit Carson yielded concordant K-Ar muscovite and biotite ages of about 47 Ma and represent the age of emplacement or reset ages (Miller and Engels, 1975; Engels and others, 1976). Bickford and others (1985) report lower U-Pb intercepts indicating ages of  $92 \pm 5$  Ma on muscovite and  $75 \pm 5$  Ma on biotite. Additional dating of the pluton has been done by Armstrong and others (1987). Two zircons yielded discordant U-Pb ages of 94 to 143 Ma. Three granitic rocks and one pegmatite gave a maximum age of  $84 \pm 4$  Ma and an initial Rb/Sr ratio of 0.7108. Two other samples analyzed by Armstrong and others (1987) contain more radiogenic Sr; calculated Rb-Sr ages are  $113 \pm 2$  Ma and  $159 \pm 3$  Ma. Armstrong and others (1987) suggest that the U-Pb ages and the Rb-Sr isochrons indicate a middle to Late Cretaceous age for the pluton.

Kiat<sub>s</sub>

Muscovite-biotite-bearing intrusive rock near the Little Spokane River (Cretaceous)--Leucocratic, medium- to coarse-grained, foliated to massive, muscovite-biotite quartz monzonite to granite that is similar to the Mount Spokane granite. Quartz is light gray and present as clusters of broken and annealed quartz grains; quartz commonly forms graphic intergrowths with feldspar. White K-feldspar is present as phenocrysts as much as 2 cm in length. Plagioclase is commonly slightly altered. Subhedral biotite comprises as much as 10 percent of the rock and forms clots. Muscovite ranges from 0 to 3 percent of the rock and is present as single euhedral crystals, in clots, or with biotite. Foliation is strongest near the Little Spokane River and fades to the north, where the intrusive body is generally massive. The body is intruded by dikes and small bodies of massive hornblende-biotite granodiorite and is cut by alaskite dikes that in places make up as much as 50 percent of the total volume. This intrusive unit yielded discordant K-Ar ages of 48 Ma on biotite and 53 Ma on muscovite (Miller and Engels, 1975). These ages are probably reset; the muscovite-biotite intrusive near the Little Spokane River is most likely of the same age as the Mount Spokane granite.

### Metamorphic Rocks in the Priest River Complex

High-grade metamorphic rocks in the Spokane quadrangle are part of the Priest River complex (PRC), which is a metamorphic core complex that has a structural and geochronological history similar to that of other Cordilleran metamorphic core complexes (Rehrig and others, 1987) (Fig. 5). The PRC is defined by a core of deformed high-grade metamorphic and igneous rocks that are in part overprinted by a mylonitic fabric and are part of the Spokane dome. The PRC is overlain by a shallow-dipping detachment fault, the Newport fault zone, which is present to the north in the Chewelah and Colville 1:100,000-scale quadrangles. Mylonitic lineation associated with Eocene extension on the Newport fault trends WSW-ENE (azimuth 70°). Greenschist-facies metasedimentary rocks and generally undeformed plutonic rocks are present on the upper plate (Miller, 1974b; Rehrig and others, 1987; Harms, 1982; Rhodes and others, 1989).

In the Spokane quadrangle, the PRC is defined by a region of amphibolite-grade gneiss, schist, and associated intrusive rocks. These rocks have been overprinted with a 4-km-thick NNE-trending, north-plunging antiformal zone of mylonitization which defines the Spokane dome, which is centered west of Spirit Lake and Rathdrum in Idaho (Rhodes, 1986). Rocks above and below the zone of mylonitization lack penetrative mylonitic fabric (Rhodes, 1986). Erosion has cut through the mylonitic zone and exposed underlying nonmylonitic rocks in the core of the dome (Rhodes and Hyndman, 1984)

Rhodes (1986) and Rhodes and others (1989) recognize two distinct metamorphic pulses in the southern part of the PRC, which includes rocks in the Spokane quadrangle. Early, steeply dipping crystalloblastic foliation is defined by oriented minerals and compositional or gneissic layering. Uppermost amphibolite-facies metamorphism is represented by the mineral assemblage of quartz + plagioclase (An<sub>25-32</sub>) + K-feldspar + biotite + sillimanite ± almandine-rich garnet; kyanite is also locally present. Partial melting is evidenced by numerous felsic pegmatite pods that exhibit mafic selvages, suggesting that deformation was synchronous with metamorphism. Sillimanite grew parallel to the foliation but without preferred linear orientation. This foliation is preserved above and below the mylonite zone and is calculated to have formed at pressures exceeding 5 kb (Rhodes, 1986).

The second phase of metamorphism recognized by Rhodes (1986) and Rhodes and others (1989) reached the middle amphibolite facies and was accompanied by mylonitization (Rhodes, 1986). A second growth of sillimanite accompanied this event, and in the mylonite zone sillimanite forms deformed bundles and coarse undeformed needles trending parallel to the N. 70° E. to S. 70° W. lineation. This lineation, which is defined by slickenside-like striae or elongate mineral grains, is also present along fold axes, which are parallel to the lineation, that fold the earlier foliation. Below the mylonite zone, sillimanite grew without preferred orientation as coarse polycrystalline mats (Rhodes, 1986; Rhodes and others, 1989). Rhodes (Rhodes and others, 1989) suggests that the east- and west-dipping mylonitic foliation on the east and west limbs of the Spokane dome, respectively, is the result of warping of the foliation into a NNE-trending arch that plunges to the north. Rehrig and others (1987) suggest that the difference in trends of the lineation is the result of two metamorphic events; they point out that the Mount Rathdrum granite is discordant with respect to the west-trending foliation, but subtly and discontinuously contains the east-trending foliation. Timing of these events is poorly constrained.

Rhodes (Rhodes and others, 1989) suggests that most of the strain associated with the 4-km mylonite zone occurred prior to the emplacement of the 52 Ma Mount Rathdrum granite and that a significant portion of the strain was synchronous with the emplacement of the Cretaceous Mount Spokane granite. Rehrig and others (1987) suggest that the PRC is typical of other Cordilleran metamorphic core complexes in that the deformational history probably began in the middle Cretaceous with deep-seated plutonism and intrusion of the muscovite-biotite-bearing rocks, metamorphism, and generation of a low-angle ductile fabric. Eocene tectonism resulted in overprinting of earlier fabrics with gently dipping mylonite foliations and zones of low-angle detachment associated with regional extension.

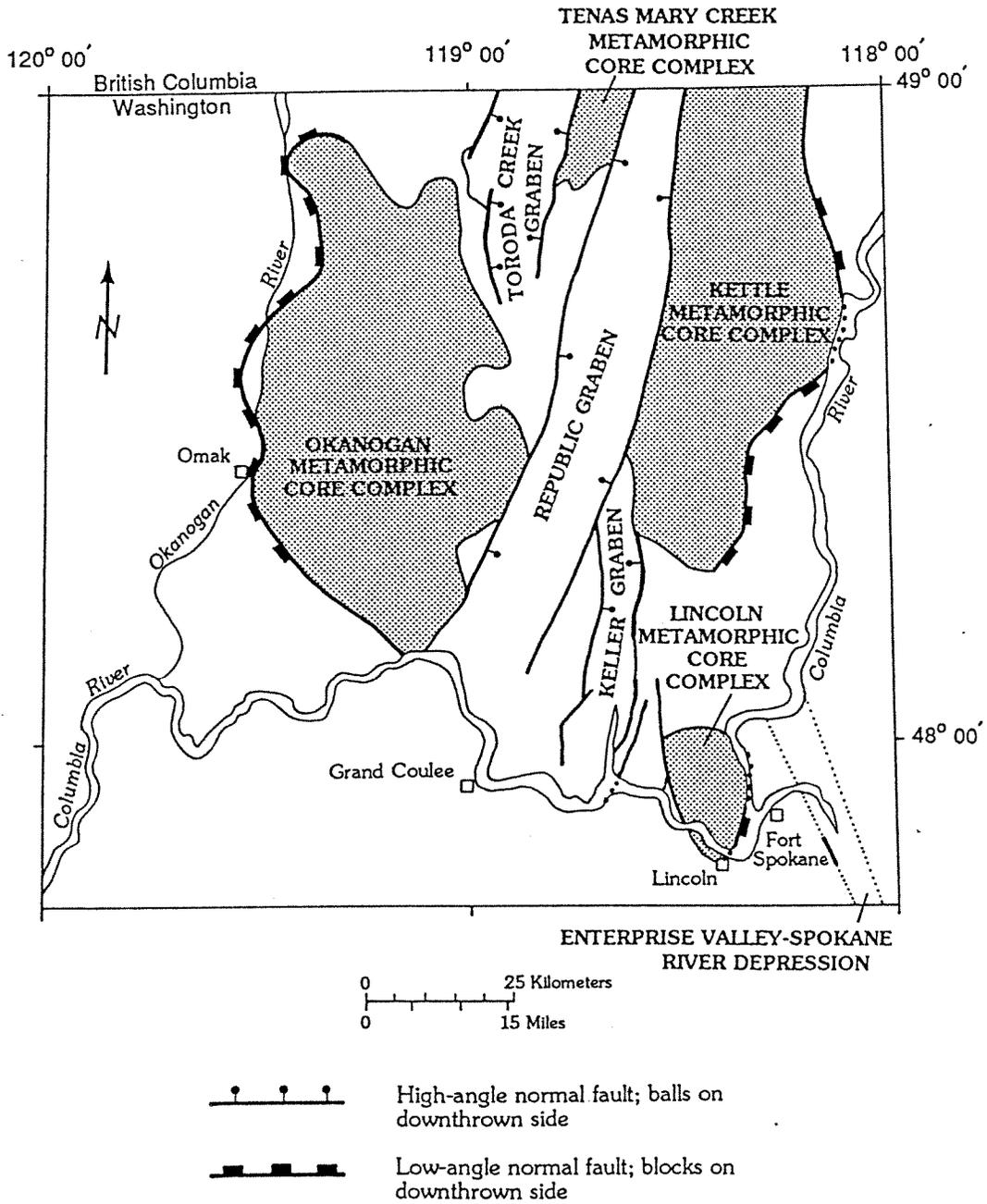


Figure 5. Location of metamorphic core complexes in northeastern Washington. (After Fox and Rinehart, 1988)

Kog<sub>n</sub>

Newman Lake Gneiss (Cretaceous)--Medium- to dark-gray, medium- to coarse-grained, mylonitic, hornblende-biotite granodiorite gneiss named by Weis (1968) for exposures on the northwest side of Newman Lake. The unit is characterized by megacrysts of subhedral to euhedral crystalloblastic orthoclase as much as 2 cm in length and contains plagioclase, K-feldspar, quartz, biotite, hornblende, and accessory titanite, allanite, zircon, apatite, and opaque minerals (Miller, 1974c).

Obvious effects of cataclasis can be seen in most thin sections. The rock was recrystallized during cataclasis, and development of a pervasive lineation is recorded by streaked-out clots of biotite (Miller, 1974c). The trend of the weak to strong lineation is consistent with the N. 70° E. to S. 70° W. trend of lineation observed elsewhere in the PRC. Crystalloblasts of K-feldspar are distinctively aligned parallel or subparallel to the foliation where the rock is strongly deformed.

The Newman Lake Gneiss is structurally overlain by the Mount Spokane granite (Rhodes and Hyndman, 1984; Bickford and others, 1985). On Beacon Hill a 2- to 5-m-thick zone containing light-colored, 0.25- to 1-m-thick bands of mylonite is interlayered with deformed Newman Lake Gneiss at the contact with the Mount Spokane granite. Elsewhere, the muscovite-megacryst-bearing granite (Kog<sub>sm</sub>) is generally present at the contact of the Newman Lake Gneiss and the Mount Spokane granite (Weissenborn and Weis, 1976); minor thin (<15 mm) mylonite zones are also present. Rhodes and Hyndman (1984) suggest that the Newman Lake Gneiss structurally overlies the Hauser Lake Gneiss.

Rb-Sr isotopic analyses of the Newman Lake Gneiss returned values similar to those for the Mount Spokane granite. Zircons yielded U-Pb ages of 45 and 139 Ma; however the data produced poor isochrons (Armstrong and others, 1987). The gneiss is thought by Armstrong and others (1987) to be Cretaceous in age. Bickford and others (1985) report a lower U-Pb intercept on mylonitic rock of 55 Ma.

Kog<sub>s</sub>

Orthogneiss near Mount Spokane (Cretaceous)--Coarse-grained, quartz-feldspar-biotite-muscovite orthogneiss that has distinctive coarse banding of light minerals and dark biotite-rich layers (Weissenborn and Weis, 1976). The structural fabric is dominated by a strong mylonitic foliation defined by mica and mylonitic lineation which lies in the plane of the foliation; lineation is defined by slickenside-like striae. The orientation of the lineation is consistently N. 70° E. to S. 70° W. (Rhodes and others, 1989)

This unit is the banded gneiss of Weissenborn and Weis (1976), which they suggested was Precambrian in age. However, Weissenborn and Weis noted that it is difficult to distinguish the orthogneiss on Mount Spokane from the Mount Spokane granite and that contacts with the Mount Spokane granite are gradational. Rhodes and Hyndman (1984) suggest that the banded gneiss of Weissenborn and Weis (1976) is the Mount Spokane granite deformed in the mylonitic zone of the PRC. The contact between the orthogneiss near Mount Spokane and the Mount Spokane granite is transitional through 500 to 1,000 m of structural thickness; the mylonitic zone is overlain by undeformed granite (Rhodes and Hyndman, 1984). The unit structurally overlies the Newman Lake Gneiss (Weissenborn and Weis, 1976).

Kog<sub>sm</sub>

Muscovite-megacryst-bearing granite near Mount Spokane (Cretaceous)--Foliated and lineated biotite-muscovite quartz monzonite east of Mount Spokane. This unit generally separates the Mount Spokane granite from the Newman Lake Gneiss. The megacryst-bearing granite is similar in composition to the Mount Spokane granite, but it has books of muscovite as much as 2.5 cm in diameter; biotite is commonly interleaved with the muscovite. At the contact with the Newman Lake Gneiss, the rock is highly sheared, and the muscovite books are obliterated (Weissenborn and Weis, 1976). The unit contains thin to thick (<2 cm to 1 m) bands of mylonite which apparently developed from alaskite dikes. The unit forms gradational contacts with the Mount Spokane granite (Kiat<sub>s</sub>), the orthogneiss on Mount Spokane (Kog<sub>s</sub>), and the Newman Lake Gneiss (Kog<sub>n</sub>) (Weissenborn and Weis, 1976).

## PCam

Amphibolite (Precambrian)--Local pods and small bodies of amphibolite containing an assemblage of plagioclase  $\pm$  hornblende, titanite, garnet, diopside, ilmenite, and quartz (Rhodes, 1986). Individual bodies are locally as thick as 28 m (Miller, 1974c). Amphibolite is shown on Plate I only in the Hauser Lake Gneiss, but it is also present in gneiss south of the Spokane River (Weis, 1968) and in the heterogeneous metamorphic rocks (PC<sub>hm</sub>) on Browns Mountain (P. L. Weis, retired USGS, oral commun., 1988).

PC<sub>bg<sub>h</sub></sub>

Hauser Lake Gneiss (Precambrian)--Rusty-weathering, medium-grained, well-banded, foliated and lineated mylonitic biotite-orthoclase-plagioclase-quartz gneiss, and schist that contains minor quartzite (Weis, 1968; Rhodes and Hyndman, 1984). Muscovite-biotite schist layers are less than 1 m thick and quartz-feldspar layers are more than 1 m thick (Miller, 1974c). The gneiss is locally intruded by abundant pods of garnet-bearing amphibolite (PC<sub>am</sub>) (Rhodes and Hyndman, 1984; Weis, 1968). The unit was named by Weis (1968) for exposures on the east side of Hauser Lake, Idaho. The unit extends in a continuous band to the north into the Chewelah 1:100,000-scale quadrangle; a structural thickness of more than 6,000 m was estimated by Weissenborn and Weis (1976).

A Precambrian age for the protolith was suggested by Weis (1968), Weissenborn and Weis (1976), Miller (1974c), and Griggs (1973). The gneiss is thought by Miller (1974c), Griggs (1973), and Rhodes (1984) to have a protolith of the Prichard Formation (Belt Supergroup). Weis (1968), Armstrong and others (1987), and Rhodes and others (1989) have suggested a pre-Beltian age for the protolith. Armstrong and others (1987) suggest a pre-Belt protolith because samples are consistently more radiogenic (Rb-Sr) than Belt Supergroup rocks. Whole-rock <sup>87</sup>Sr/<sup>86</sup>Sr analyses of 13 samples suggest an age of 2,053 Ma for the Hauser Lake Gneiss, whereas euhedral zircons indicate a discordant age of 1,668  $\pm$  32 Ma. Augen gneiss that intrudes the Hauser Lake Gneiss near Priest River, Idaho, yielded a single whole-rock Rb-Sr age of 1,440 Ma (Clark, 1973). Armstrong and others (1987) suggest that an old age is indicated for the metamorphic banding because of the large layer-to-layer variation in Sr isotopic composition (Armstrong and others, 1987). According to Armstrong and others (1987), a major metamorphic event to create that banding might be dated at 1,670 Ma, on the basis of the upper intercept obtained from zircons.

Rhodes and others (1989) correlate the rusty-weathering sillimanite-bearing paragneiss and schist south of the Spokane Valley with the Hauser Lake Gneiss. The gneiss south of the river has a gently dipping lineation and non-penetrative mylonitic foliation and is thought by Rhodes (1986) to be below the mylonitic zone on the south limb of a synform that has its axis parallel to the Spokane River valley.

The Hauser Lake Gneiss is structurally overlain by the Cretaceous Newman Lake Gneiss (Weissenborn and Weis, 1976; Rhodes and Hyndman, 1984; Rhodes and others, 1989). The gneiss unit is intruded by the foliated and lineated dikes of the Mount Rathdrum granite (Eiat<sub>g</sub>), which cut the foliation in the gneiss.

PC<sub>hm</sub>

Heterogeneous metamorphic rocks (Precambrian)--Light- to medium-gray, medium- to coarse-grained, prominently layered gneiss, schist, and quartzite present south of the Spokane River. In the Dishman Hills and near Glenrose, the unit appears to be predominantly feldspathic orthogneiss that displays compositional banding and injected layers composed of biotite, muscovite, feldspar, and quartz. On Browns Mountain and south of hill 881 (3 km northwest of Chester), the unit is predominantly biotite-bearing, medium- to coarse-grained, medium- to thick-layered quartzite and interbedded medium- to coarse-grained biotite-muscovite and muscovite-biotite schists.

Dark-colored graphitic schist and light- to dark-colored schist interlayered with quartzite are present on Silver Hill. Dark-gray to black, fine-grained graphitic schist contains quartz, pink crystalline andalusite, biotite, muscovite, and locally abundant tourmaline. Light- to dark-gray sillimanite-biotite schist to gneiss is interlayered with quartzite and also contains quartz, biotite, andalusite, tourmaline, and muscovite. Dark-gray to black, fine-grained, massive quartzite is composed of quartz and minor muscovite, biotite, feldspar, andalusite, sillimanite, and graphite (McLeod, 1923). McLeod (1923) suggests that the tourmaline content of the schist increases with proximity to the granitic rocks (TKia).

The unit is cut by alaskite pegmatite dikes; alaskite on Krell Hill and near Big Rock generally intrudes the quartzite of the heterogeneous metamorphic unit parallel to subparallel to foliation. Schist and quartzite on Silver Hill are intruded by biotite-bearing intrusive rocks (TKia) (Page, 1942). On Browns Mountain biotite schist and paragneiss are cut by biotite-hornblende diorite and amphibolite of probable Precambrian age (P. L. Weis, retired USGS, oral commun., 1988). The contact relations of the gneiss with lower grade rocks of the Ravalli Group are not known.

#### PCqz

Quartzite near Freeman (Precambrian)--Medium-grained, thin- to thick-bedded quartzite. Five to 35 meters of massive, white quartzite are present at the base of the unit and grade upward into gray, thin- to medium-layered, arkosic quartzite and micaceous feldspathic quartzite containing 60 to 90 percent quartz. The unit is intruded by pegmatitic bodies. The contact with the underlying gneiss of Mica Peak (PCbg<sub>m</sub>) is sharp (Weis, 1968). The quartzite is thought to be part of the Prichard Formation by Griggs (1973) and to be older than the Belt Supergroup by Weis (1968).

#### PCbg<sub>m</sub>

Gneiss of Mica Peak (Precambrian)--Light-gray, coarse-grained muscovite-quartz-feldspar schist and segregation gneiss that consists of mica-rich layers separating quartz-feldspar layers. The schist commonly contains more than 50 percent mica and is locally contorted. Sillimanite and biotite are locally present. Concordant and discordant granitic bodies make up as much as 50 percent of the unit. Small scattered amphibolite bodies intrude the gneiss in the eastern part of the unit. The contact with the underlying gneiss (PCsc<sub>r</sub>) is gradational through 5 to 35 m (Weis, 1968). The unit is thought to be part of the Prichard Formation by Griggs (1973) and to be older than the Belt Supergroup by Weis (1968).

#### PCsc<sub>r</sub>

Gneiss near Round Mountain (Precambrian)--Light pinkish gray, medium- to fine-grained, quartz-feldspar-muscovite-sillimanite schist and gneiss. The gneiss is poorly layered and contains abundant small folds. It is intruded by sparse pegmatite and granitic dikes and minor small amphibolite bodies. The contact with gneiss near Cable Peak (PCbg<sub>c</sub>) is poorly exposed (Weis, 1968). The gneiss near Round Mountain is thought to be part of the Prichard Formation by Griggs (1973) and to be older than the Belt Supergroup by Weis (1968).

#### PCbg<sub>c</sub>

Gneiss near Cable Peak (Precambrian)--Light- to dark-gray, chiefly medium-gray, prominently layered gneiss and schist. Individual layers are generally less than 15 cm thick and include quartzite, feldspathic quartzite, and micaceous quartz-feldspar gneiss, granitic gneiss, amphibolite, and schist. The gneiss characteristically has a wide range of composition in adjacent layers (Weis, 1968). The gneiss is thought to be part of the Prichard Formation by Griggs (1973) and to be older than the Belt Supergroup by Weis (1968).

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SPOKANE 1:100,000 QUADRANGLE

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**Table 1.** Radiometric age data for the Spokane 1:100,000-scale quadrangle

Sample locality	Sample number	Unit	Map symbol	Location	Method	Material	Age (millions of years)	Reference
1	OJW-64-01	Grande Ronde basalt	Mv <sub>gn2</sub>	47° 39.9' 117° 28.3'	K-Ar	plagioclase	14.2 ± 1	Engels and others, 1976
2	OJW-64-02	Priest Rapids Member of Wanapum Basalt	Mv <sub>wp</sub>	47° 38.3' 117° 29.3'	K-Ar	plagioclase	15.5 ± 0.8	Engels and others, 1976
2	OJW-64-02	Priest Rapids Member of Wanapum Basalt	Mv <sub>wp</sub>	47° 38.3' 117° 29.3'	K-Ar	plagioclase	15.0 ± 0.9	Engels and others, 1976
3	DA-20	alaskite, pegmatite & aplite	Tk <sub>iaa</sub>	47° 57' 117° 12'	Pb-alpha	monazite	75 ± 10	Engels and others, 1976
28	66	muscovite-biotite-bearing intrusive rock near the Little Spokane River	Kiat <sub>s</sub>	47° 47' 117° 28'	K-Ar	biotite muscovite	47.6 ± 2.6 52.9 ± 1.6	Miller and Engels, 1975
5	65	Mount Spokane granite	Kiat <sub>s</sub>	47° 51' 117° 11'	K-Ar	biotite muscovite	47.3 ± 1.6 47.5 ± 1.9	Miller and Engels, 1975
6	64	Mount Spokane granite	Kiat <sub>s</sub>	47° 51' 117° 10'	K-Ar	biotite muscovite	47.1 ± 1.4 48.7 ± 1.7	Miller and Engels, 1975
7	RS-77-1	Mount Spokane granite	Kiat <sub>s</sub>	47° 52.7' 117° 13.0'	Rb-Sr	whole rock and biotite	51 ± 2	Armstrong and others, 1987
8	RS-77-1,2,3	Mount Spokane granite, alaskite	Kiat <sub>s</sub> Tk <sub>iaa</sub>	47° 52.7' 117° 13.0' 47° 50.25' 117° 11.0'	Rb-Sr	whole rock	84 ± 4	Armstrong and others, 1987
9	RS-77-2	alaskite, pegmatite, and aplite	Tk <sub>iaa</sub>	47° 52.7' 117° 13.0'	Rb-Sr	whole rock and muscovite	47 ± 16	Armstrong and others, 1987
10	RS-77-4	alaskite, pegmatite, and aplite	Tk <sub>iaa</sub>	47° 52.0' 117° 09.7'	Rb-Sr	whole rock	159 ± 3	Armstrong and others, 1987

**Table 1.** Radiometric age data for the Spokane 1:100,000-scale quadrangle (continued)

Sample locality	Sample number	Unit	Map symbol	Location	Method	Material	Age (millions of years)	Reference
11	RS-77-5	alaskite, pegmatite, and aplite	Tkiaa	47° 51.3' 117° 09.8'	Rb-Sr Rb-Sr	whole rock whole rock and muscovite	113 ± 2 40 ± 6	Armstrong and others, 1987
12	Mount Spokane	Mount Spokane granite	Kiat <sub>s</sub>	47° 50.25' 117° 11.0'	U-pb	zircon	94 to 143	Armstrong and others, 1987
13	mtsk 77-2	Newman Lake Gneiss	Kog <sub>n</sub>	47° 48.0' 117° 07.1'	Rb-Sr	whole rock and biotite	45 ± 2	Armstrong and others, 1987
14	Newman Lake	Newman Lake Gneiss	Kog <sub>n</sub>	47° 46.7' 117° 07.0	U-pb	zircon	97, 139	Armstrong and others, 1987
15	1W7	Hauser Lake Gneiss	pCb <sub>g</sub> <sub>h</sub>	47° 46' 117° 05'	Pb-alpha	zircon	1150 ± 130	Weis, 1968
16	1W8	heterogeneous metamorphic rocks	pCb <sub>g</sub> <sub>h</sub>	47° 35' 117° 15'	Pb-alpha	zircon	1120 ± 130	Weis, 1968
17	mtsk 77-1	Hauser Lake Gneiss	pCb <sub>g</sub> <sub>h</sub>	47° 46.2' 117° 05.9'	Rb-Sr	whole rock and biotite	45 ± 3	Armstrong and others, 1987
18	79-10-16	Hauser Lake Gneiss (migmatitic)	pCb <sub>g</sub> <sub>h</sub>	47° 47' 117° 01'	U-pb	zircon	1,668 ± 32 (upper intercept) 70 ± 17 (lower intercept)	Armstrong and others, 1987
19	Chester - 3E	heterogeneous metamorphic rocks (pegmatite)	pChm	47° 34.5' 117° 14.5'	Rb-Sr	whole rock	1,600	Armstrong and others, 1987
20	Chester - 2PEG	heterogeneous metamorphic rocks (muscovite from pegmatite)	pChm	47° 34.4' 117° 13.8'	Rb-Sr	whole rock and muscovite	54 ± 3	Armstrong and others, 1987

Decay constants:  $^{238}\text{U}\lambda = 0.155125 \times 10^{-9} \text{ yr}^{-1}$ ;  $^{235}\text{U}\lambda = 0.98485 \times 10^{-9} \text{ yr}^{-1}$ ;  $^{238}\text{U}/^{235}\text{U} = 137.88$   
Rb-Sr:  $\lambda(^{87}\text{Rb})1.42 \times 10^{-11} \text{ yr}^{-1}$   
K-Ar:  $\lambda_p = 4.72 \times 10^{-10} \text{ yr}^{-1}$ ;  $\lambda_t = 0.584 \times 10^{-10} \text{ yr}^{-1}$ ;  $^{40}\text{K}/K_{\text{total}} = 1.19 \times 10^{-4}$