
**GEOLOGIC MAP OF THE
OROVILLE
1:100,000 QUADRANGLE, WASHINGTON**

Compiled by
KEITH L. STOFFEL

**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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INTRODUCTION

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

Literature review and preliminary compilation of the Oroville quadrangle geologic map began in 1985. Between 1986 and 1988, reconnaissance and detailed geologic mapping was performed by DGER geologists in areas where previous geologic mapping was either inadequate or lacking. New geologic mapping was also acquired during that time through a DGER graduate student mapping program. Figure 2 is an index map showing sources of geologic map data used for compilation of the Oroville quadrangle map (Plate 1).

Age assignments of geologic units on the Oroville 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 radiometric ages from the Oroville 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 volcanic rock names. New whole-rock geochemical data, from samples collected by DGER geologists, are given in Tables 2 and 3 (following Table 1).

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, 51 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.

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.

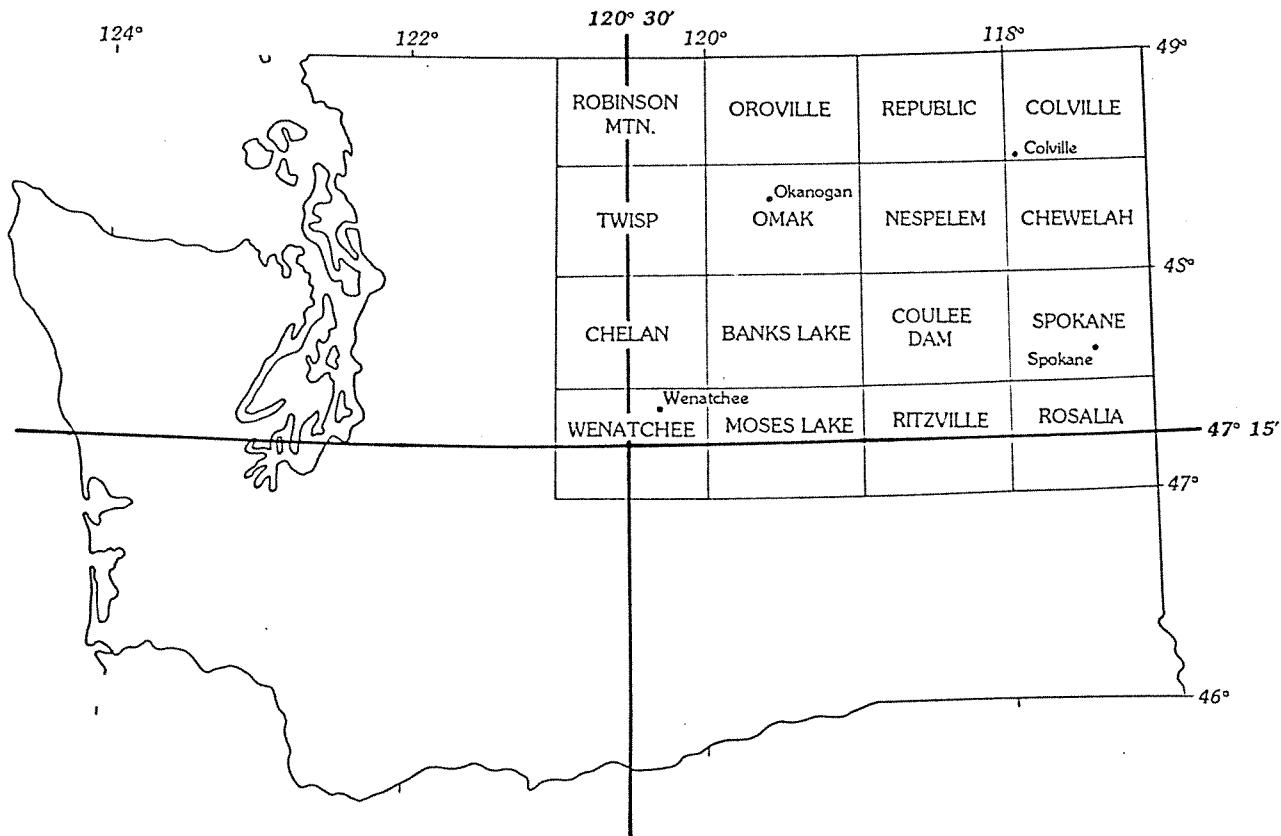


Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Sources of Map Data

(Explanation for Figure 2, facing page)

1. Buddington, A. M., Western Washington University, written commun., 1987, scale 1:24,000.
2. Cheney and others, 1982, scale 1:250,000.
3. Fox, 1970, scale 1:48,000.
4. Fox, 1978, scale 1:48,000.
5. Fox, K. F., Jr.; Rinehart, C. D., USGS, written commun., 1988, scale 1:48,000.
6. Gulick, 1987, scale 1:24,000.
7. Hibbard, 1971, scale 1:62,500.
8. McMillen, 1979, scale 1:31,680.
9. Menzer, 1982, scale 1:63,360.
10. Orr and Cheney, 1987, scale 1:457,600, stippled area, DGER unpublished mapping, this report.
11. Pine, 1985, scale 1:24,000.
12. Rinehart, 1981, scale 1:96,000.
13. Rinehart and Fox, 1972, scale 1:62,500.
14. Rinehart and Fox, 1976, scale 1:62,500.
15. Rinehart, C. D.; Fox, K. F., Jr., USGS, written commun., 1988, scale 1:48,000.

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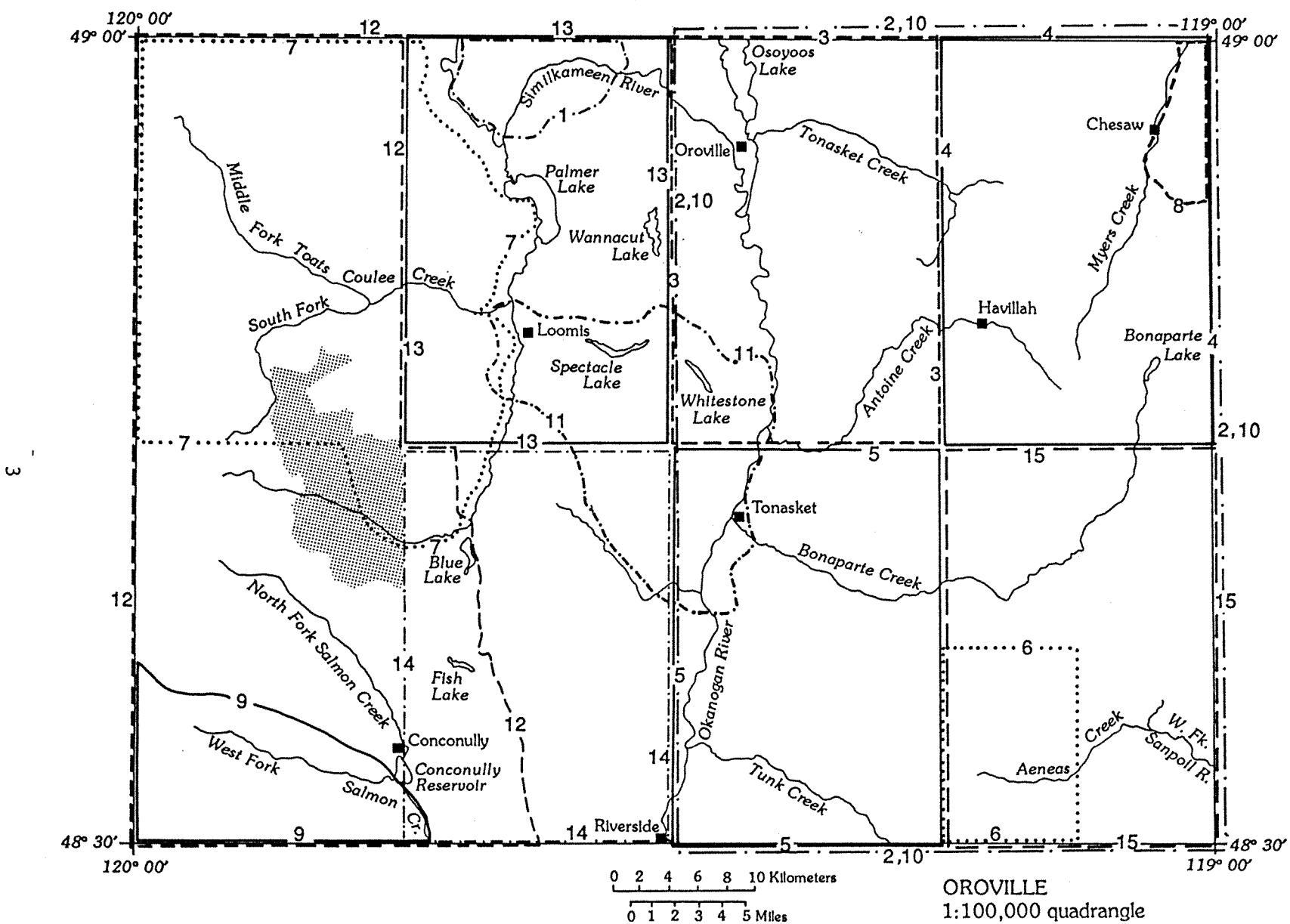


Figure 2. Sources of geologic map data for the Oroville 1:100,000-scale quadrangle. See facing page for explanation.

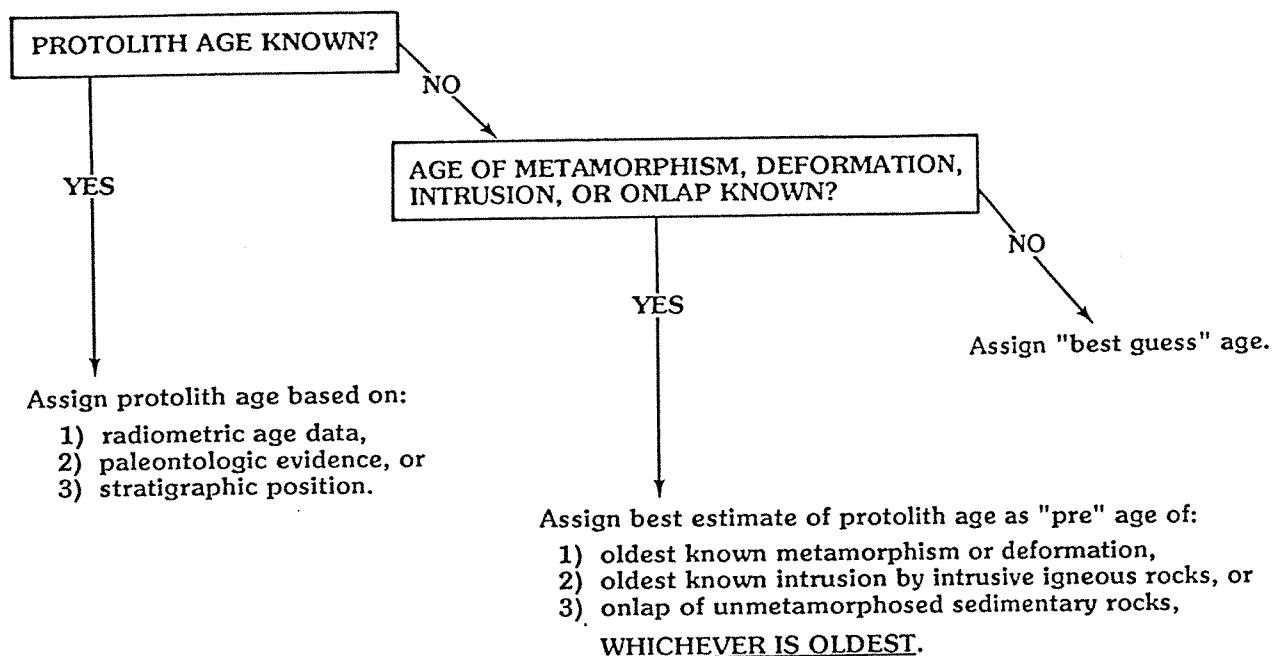


Figure 3. Flow chart for age assignment of geologic units. Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description will include information on how the age of the unit was determined.

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.

Stoffel, K. L., compiler, 1990, Geologic map of the Oroville 1:100,000-scale 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-scale quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-10, 62 p., 1 pl.

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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-scale 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-scale 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-scale quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-7, 20 p., 1 pl.

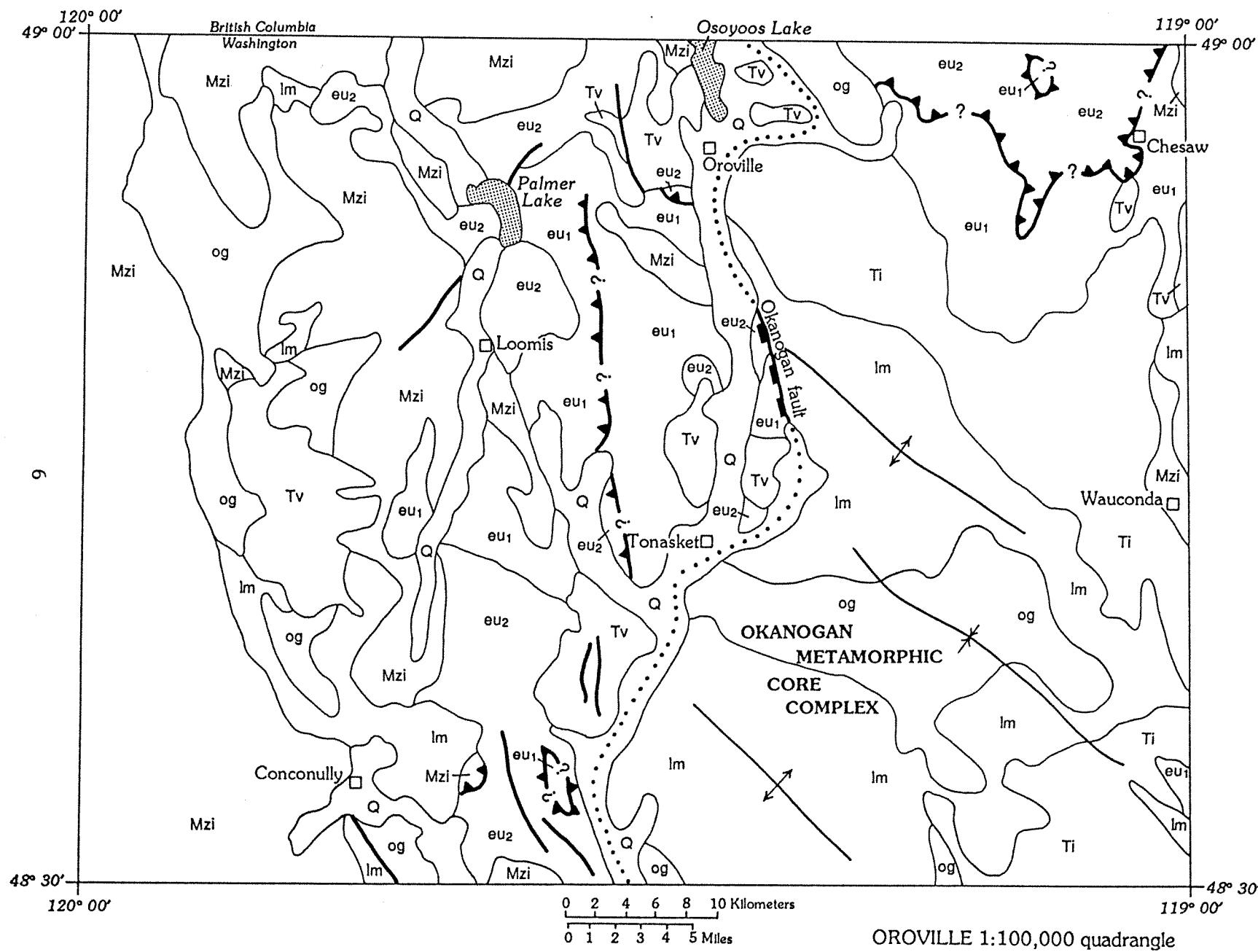
Acknowledgments

This geologic map is the culmination of the efforts of dozens of geologists over the better part of a century. All have made vital contributions to the accuracy of the map, but obviously only a few can be cited here. Special thanks to:

- * E. S. Cheney, H. W. Schasse, M. A. Korosec, A. M. Buddington, and C. D. Rinehart for thorough and constructive reviews of an earlier draft of the manuscript
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GEOLOGIC SETTING

The Oroville 1:100,000-scale quadrangle contains five generalized rock packages (Fig. 4): (1) amphibolite-facies layered metamorphic rocks and orthogneiss; (2) greenschist-facies Paleozoic and early Mesozoic eugeoclinal rocks; (3) Mesozoic igneous intrusions; (4) Tertiary igneous intrusions; and (5) Tertiary sedimentary and volcanic rocks. The eugeoclinal rocks were deposited in subsiding basins peripheral to or within a series of Paleozoic and Mesozoic volcanic archipelagos, and they were subsequently accreted to the North American continent during the Late Triassic or Early Jurassic. Plutonism and regional metamorphism accompanied accretion. Plutonism continued into the Late Cretaceous. Penetrative deformation and uplift of the amphibolite-facies metamorphic rocks in the Okanogan metamorphic core complex, intrusion of plutonic rocks, and deposition of volcanic and sedimentary rocks occurred during Late Cretaceous and early Tertiary regional extension.



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DESCRIPTION OF MAP UNITS

Sedimentary and Volcanic Deposits and Rocks

Quaternary Sedimentary Deposits

Nonglacial Deposits

Qa

Alluvium (Holocene)--Silt, sand, and gravel on modern floodplains and alluvial fans

Qoa

Older alluvium (Pleistocene)--Silt, sand, and gravel in terraces above the modern floodplain of the Okanogan River

Qp

Peat (Holocene)--Peat and organic-rich lacustrine sediments; chiefly in marshy areas along shorelines of lakes

Qls

Mass-wasting deposits (Holocene)--Landslide deposits, talus, and colluvium

Qd

Dunes (Holocene)--Well sorted, fine sand in eolian dunes along the east side of Osoyoos Lake

Explanation for Figure 4 (facing page)

Q	Quaternary sediments
Tv	Tertiary volcanic and sedimentary rocks
Ti	Tertiary intrusive igneous rocks
Mzi	Mesozoic intrusive igneous rocks
eu ₂	Jurassic and Triassic(?) eugeoclinal rocks
eu ₁	Permian and Ordovician(?) eugeoclinal rocks
Im	layered metamorphic rocks (amphibolite-facies)
og	orthogneiss

See plate 1 for explanation of map symbols.

Figure 4. Generalized geologic map, Oroville 1:100,000 quadrangle.

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Glacial Deposits

Qgt

Till (Pleistocene)--Unstratified to poorly stratified deposits composed of subrounded to subangular pebbles, cobbles, and boulders in an unsorted matrix of sand, silt, and clay; contains lenses of glaciofluvial and glaciolacustrine sediments; locally overlain by thin deposits of stratified glacial outwash

Qgo

Glacial outwash (Pleistocene)--Stratified silt, sand, and gravel in outwash plains, kame terraces, kames, and eskers. The outwash deposits consist of massive to crudely bedded, pebbly gravel with thin interbeds of cross-stratified sand. The kame terraces, kames, and eskers are heterogeneous deposits of silt and fine sand, pebbly gravel, and minor till.

Qgl

Glaciolacustrine deposits (Pleistocene)--Thinly laminated clay, silt, and fine sand with abundant graded rhythmites and climbing ripple cross-laminations

Qgd

Glacial drift (Pleistocene)--Unconsolidated glacial debris, including till, glaciofluvial sand and gravel, and glaciolacustrine silt and clay; fills valleys and mantles uplands throughout the map area; includes some colluvium on slopes and alluvium along floodplains

Tertiary Sedimentary and Volcanic Rocks

Evdv_k, Ec_k

Klondike Mountain Formation (Eocene)--Eocene sedimentary and volcanic rocks crop out along the West Fork Sanpoil River in the southeastern corner of the Oroville 1:100,000-scale quadrangle and the southwestern corner of the Republic 1:100,000-scale quadrangle (Cheney and others, 1982; Orr and Cheney, 1987; Rinehart and Greene, 1988; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988). These rocks are an erosional remnant of the Klondike Mountain Formation, which forms an extensive belt along the western border of the Republic 1:100,000-scale quadrangle to the northeast (Pearson, 1967; Muessig, 1967; Rinehart and Greene, 1988; Stoffel, 1990). Along the West Fork Sanpoil River, the Klondike Mountain Formation consists of an upper unit of vitrophyric and microcrystalline dacite and andesite flows (Evdv_k) and a basal unit of volcanic sandstone, siltstone, and shale (Ec_k).

Klondike Mountain Formation sedimentary rocks in the Republic 1:100,000-scale quadrangle contain the remarkably diverse, early middle Eocene "Republic flora" (Wolfe and Wehr, 1987). K-Ar ages from Klondike Mountain Formation flows in the Republic 1:100,000-scale quadrangle range from 41.3 ± 2.0 Ma to 48.0 ± 1.9 Ma (Pearson and Obradovich, 1977; Stoffel, 1990).

Evd_k

Vitrophyric and microcrystalline dacite and andesite flows--Microcrystalline flows and vitrophyric flow breccias. The flow breccias are composed of angular blocks of black vitrophyre in a matrix of finely crushed vitrophyric rock fragments. The vitrophyre is composed of sparse plagioclase and clinopyroxene phenocrysts in a glassy groundmass that contains abundant plagioclase and clinopyroxene microlites. Minor orthopyroxene and olivine phenocrysts occur locally. The composition of the microcrystalline flows is similar to that of the glassy flows, but the groundmass of the microcrystalline rocks is holocrystalline and contains no glass. Whole-rock, major- and trace-element geochemical analyses of the vitrophyric and microcrystalline flows in the Republic 1:100,000-scale quadrangle indicate the rocks are dacitic to andesitic in composition (Stoffel, 1990). This unit forms the upper 200 m of the Klondike Mountain Formation along the West Fork Sanpoil River.

Ec_k

Sedimentary rocks--Thin-bedded sandstone, siltstone, shale, and minor conglomerate. The sandstone is composed of plagioclase grains and volcanic rock fragments in a matrix of clay and calcite. The conglomerate consists of subangular rock clasts, as much as 10 cm across, in a sandy matrix similar in composition to the sandstone. Hornblende-bearing granitoid rocks are the dominant clast type; metamorphic and volcanic rock fragments are subordinate.

Evd_s

Sanpoil Volcanics (Eocene)--Massive porphyritic dacite and andesite flows. These altered purple, green, and gray rocks consist of plagioclase, hornblende, and biotite phenocrysts in an aphanitic groundmass of feldspar and quartz. The unit crops out along Myers Creek south of Chesaw (T. 39 N., R. 30 E.) (Fox, 1978). The rocks are compositionally similar to the Sanpoil Volcanics in the Republic 1:100,000-scale quadrangle (Muessig, 1962, 1967) and are probably correlative with them.

Ec_o

O'Brien Creek Formation (Eocene)--Massive to well-bedded, cream and pale-green, tuffaceous sandstone and crystal tuff with minor interbedded siltstone and carbonaceous shale. The tuff and tuffaceous sandstone are composed of broken crystals of plagioclase, quartz, and K-feldspar in a glassy to cryptocrystalline groundmass. They contain abundant angular chips of dark-gray argillite. Feldspathic sandstone and conglomerate are present locally, particularly near the base of the formation. The conglomerate consists of subrounded to rounded clasts of a wide variety of metamorphic and intrusive rocks in a sandy matrix of quartz and feldspar.

The O'Brien Creek Formation crops out along Beaver Creek in the northeastern corner of the Oroville 1:100,000-scale quadrangle and the northwestern corner of the Republic 1:100,000-scale quadrangle (Muessig, 1967; Pearson, 1967; Fox, 1978). It unconformably overlies greenschist-facies metamorphic rocks in places, but contacts are commonly marked by faults. In the Republic 1:100,000-scale quadrangle, the contact between the O'Brien Creek Formation and the overlying Sanpoil Volcanics is generally conformable and gradational.

Because no reliable radiometric ages have been reported from the O'Brien Creek Formation, the age of the formation is uncertain. Bedded tuff in the Pend Oreille valley near the Idaho border, tentatively assigned to the O'Brien Creek Formation (Pearson and Obradovich, 1977), has yielded a K-Ar biotite age of 53.1 ± 1.5 Ma.

Evc_a, Evd, Evt, Evc_o, Ec, Ecg, Ev

Other Eocene sedimentary and volcanic rocks--Eocene sedimentary and volcanic rocks are also exposed near Oroville, on Whitestone and Duffys Mountains near Tonasket, at Carter Mountain (T. 36 N., R. 26 E.), near Sinlahekin Creek (T. 37 N., R. 24 E.), and on Bimetallic Mountain near Havillah (T. 39 N., R. 29 E.). Conglomerate, sandstone, and siltstone composed of plutonic and metamorphic rock detritus form the base of the Eocene strata. The sedimentary rocks are overlain by a heterogeneous package of pyroclastic and volcaniclastic rocks that is, in turn, overlain by a thick sequence of porphyritic dacite and andesite flows. Volcanic conglomerate and sandstone locally overlie the flows. Hypabyssal intrusions that are compositionally similar to the flows cut the stratified volcanic and sedimentary rocks in places.

These Eocene sedimentary and volcanic rocks are temporally correlative with the O'Brien Creek Formation, Sanpoil Volcanics, and Klondike Mountain Formation in the Republic and Nespelem 1:100,000-scale quadrangles to the east. The sedimentary rocks (Ec, Ecg) at the base of the Eocene strata are probably correlative with the O'Brien Creek Formation. The pyroclastic rocks (Evt) and volcaniclastic rocks (Evc_o) are correlative with either the O'Brien Creek Formation or the Sanpoil Volcanics. Modal and geochemical compositions of the porphyritic dacite and andesite flows (Evd) are similar to those of flows in the Sanpoil Volcanics (Table 2), but K-Ar ages from the porphyritic dacite and andesite flows in the map area indicate that they erupted between 42.9 ± 1.3 Ma and 49.1 ± 1.8 Ma (Table 1), during deposition of both the Sanpoil Volcanics and the Klondike Mountain Formation to the east. The volcaniclastic rocks (Evc_a) that overlie the porphyritic flows may be correlative with part of the Klondike Mountain Formation.

Evc_a

Volcaniclastic rocks along Antoine Creek (Eocene)--Volcaniclastic rocks that crop out along both sides of Antoine Creek northeast of Tonasket (secs. 35 and 36, T. 38 N., R. 27 E.) (Woodward, 1936; Fox, 1970; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). The rocks on Duffys Mountain south of Antoine Creek are a 60-m-thick sequence of interbedded volcanic sandstone and conglomerate, shale, tuff, and tuff breccia. The rocks north of Antoine Creek are chiefly massive to crudely stratified volcanic conglomerate with a few interbeds of shaly sandstone. The conglomerate consists of subrounded to subangular clasts of porphyritic dacite and andesite, tuff, shale, schist, phyllite, granite, and aplite. The clasts are set in a sandy tuffaceous matrix.

The volcaniclastic rocks along Antoine Creek overlie the porphyritic dacite and andesite flows (Evd). They are probably the youngest volcanic rocks in the western part of the map area.

Evd

Porphyritic dacite and andesite flows (Eocene)--Massive to flow-banded gray, purple, or green porphyritic flows that consist of 1- to 3-mm-long euhedral phenocrysts of plagioclase, hornblende, and minor biotite, augite, and quartz set in an aphanitic groundmass of K-feldspar, quartz, and plagioclase. Phenocrysts compose as much as 40 percent of the rocks. Plagioclase phenocrysts are chiefly andesine and labradorite. Whole-rock, major-element geochemical analyses of the porphyritic flows indicate compositions ranging from dacite to andesite (Table 2).

The porphyritic dacite and andesite flows are commonly strongly altered. Laumontite, albite, and/or oligoclase are secondary after plagioclase. Chlorite, calcite, epidote, magnetite/hematite, and zeolites replace mafic minerals.

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The porphyritic dacite and andesite flows crop out near Sinlahekin Creek, Carter Mountain, Whitestone Mountain, Duffys Mountain, and Osoyoos Lake (Fox, 1970; Rinehart and Fox, 1972, 1976; Rinehart, 1981; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988; DGER unpublished mapping). The flows are generally conformable with the underlying tuff unit, but they locally fill channels cut into the tuff, and they unconformably overlie pre-Tertiary rocks in places. Thin interbeds of tuff are intercalated with the flows in places. The thickest section (approximately 600 m) of these flows occurs near Carter Mountain (Rinehart and Fox, 1976).

Evt

Tuff and tuff breccia (Eocene)--Crystal-lithic tuff and crystal tuff. The tuff is typically white, light gray, or pale shades of brown, red, or green. It consists of 1- to 2-mm-long, broken to euhedral crystals of plagioclase (chiefly oligoclase-andesine), K-feldspar, quartz, hornblende, and minor biotite in a cryptocrystalline groundmass. Flattened dark-green or brown pumice clasts occur locally. The tuff breccia consists of abundant angular to subrounded clasts of porphyritic hornblende-bearing volcanic rocks in a matrix similar in composition to the tuff. One whole-rock geochemical analysis of the tuff at Carter Mountain plots in the rhyolite field on the total alkali-silica (TAS) diagram (Rinehart and Fox, 1976). Thin beds and lenses of tuffaceous siltstone, sandstone, and conglomerate are intercalated with the tuff and tuff breccia in places.

The tuff and tuff breccia form a thick stratigraphic unit at Whitestone, Duffys, and Carter Mountains and near Sinlahekin Creek (Woodward, 1936; Fox, 1970; Rinehart and Fox, 1972; Rinehart, 1981; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988; DGER unpublished mapping). The tuff unit is thickest (approximately 600 m) near Carter Mountain. The tuff and tuff breccia generally form massive outcrops, but crude bedding is developed in places.

The tuff unit locally overlies and grades into Eocene sedimentary rocks (Ec, Ecg), but it generally unconformably overlies pre-Tertiary rocks. The tuff unit is conformably overlain by porphyritic dacite and andesite flows in most places. It is probably coeval with the volcaniclastic rocks unit near Oroville (Evc_o).

Evc_o

Volcaniclastic rocks near Oroville (Eocene)--Pale-green to gray-green crystal-lithic tuff consisting of broken to euhedral plagioclase and quartz crystals, altered hornblende(?) crystals replaced by calcite-chlorite intergrowths, and clasts of devitrified glass, in a matrix of fine-grained chlorite that grades upward into interbedded volcanic lithic sandstone and conglomerate composed of rounded pebbles and cobbles of aphanitic volcanic rocks in a crystal tuff matrix. The volcanic conglomerate grades upward into conglomerate and lithic sandstone composed of angular clasts of metamorphic and volcanic rocks.

This volcaniclastic unit forms a thick stratigraphic unit near Oroville (Fox, 1970; Rinehart and Fox, 1972). There, these rocks overlie Eocene sedimentary rocks (Ec, Ecg) composed of metamorphic and igneous rock fragments. East of Oroville, the volcaniclastic rocks are overlain by porphyritic dacite flows. West of Oroville, the volcaniclastic rocks are intruded by plugs of porphyritic dacite.

Ec, Ecg

Sedimentary rocks (Eocene)--Conglomerate, feldspathic sandstone and siltstone, and shale that form the basal unit of the Eocene strata in the map area. The thickest section of these sedimentary rocks (1,150 m) is northwest of Oroville. Thinner sections of sedimentary rocks crop out along the west

side of Whitestone Mountain, near Carter Mountain, near Sinlahekin Creek, and along the southeastern flank of Bimetallic Mountain (T. 39 N., R. 29 E.). The sedimentary rocks unconformably overlie metasedimentary, metamorphic, and igneous rocks, and are conformably overlain by and locally grade into volcaniclastic rocks (Evc_o) and tuff (Evt). The sedimentary rocks contain a diverse assemblage of fossil flora of middle Eocene age (Rinehart and Fox, 1972). The sedimentary rocks near Oroville are cut by plugs of porphyritic dacite that have yielded K-Ar hornblende ages of 51.4 ± 2.6 Ma and 52.1 ± 2.3 Ma (Rinehart and Fox, 1972).

The Eocene sedimentary rocks near Oroville form a homoclinal sequence that dips approximately 30° to the east (Fox, 1970; Rinehart and Fox, 1972). The lower part of the sequence is dominated by conglomerate with minor feldspathic sandstone (Ec_g). The conglomerate consists of subrounded to rounded metamorphic rock clasts in a poorly sorted, sandy matrix. Most of the clasts are between 1 and 2 cm in diameter, but boulders as much as 1 m in diameter are also present. This conglomerate grades upward into conglomerate composed chiefly of granodiorite clasts in a fine- to coarse-grained feldspathic sandstone matrix. Minor malignite, syenite, metachert, and greenstone clasts are also found. The clasts are generally between 2 and 4 cm in diameter, but boulders more than 1 m in diameter are not uncommon. The granodiorite conglomerate grades upward and eastward into interbedded feldspathic sandstone and siltstone with minor lenses of pebble conglomerate (Ec). The fine- to coarse-grained sandstone consists of subangular grains of quartz, feldspar, and less than 10 percent mafic minerals in a clay-carbonate matrix. Small pebbles of metamorphic rocks are scattered throughout the sandstone. Conglomerate lenses in the sandstone are composed of rounded pebbles of metamorphic rocks, as much as 4 cm across, in a feldspathic sandstone matrix.

Conglomerate dominates the lower half of the Eocene sedimentary rocks at Whitestone Mountain (Woodward, 1936; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). It is massive to crudely stratified, poorly sorted, and composed of rounded to subangular clasts (from less than 1 cm to more than 1 m across) in a coarse-grained sandy matrix of quartz, plagioclase, K-feldspar, muscovite, biotite, and phyllite chips. Clasts include granite, gneiss, schist, phyllite, greenstone, limestone, quartzite, hornfels, and chert; granite is most abundant. Interbedded feldspathic sandstone and siltstone, shale, and minor tuff and conglomerate make up the upper 215 m of the sedimentary rocks at Whitestone Mountain. Beds range from less than 1 m to more than 6 m thick. Principal constituents of the sandstone and siltstone are K-feldspar, quartz, plagioclase, muscovite, and biotite. Cross-beds and ripple marks are common in the sandstone. Plant fossils are abundant in the shale.

Conglomerate and sandstone dominate the sedimentary rocks at Carter Mountain and near Sinlahekin Creek (Goldsmith, 1952; Rinehart and Fox, 1976; Rinehart, 1981; DGER unpublished mapping). The conglomerate is massive to crudely stratified, poorly sorted, and matrix supported. It consists of rounded to subangular clasts of metamorphic and plutonic rocks, as much as 1 m in diameter, in a matrix of medium- to coarse-grained sandstone composed chiefly of quartz and feldspar. Along Sinlahekin Creek (sec. 13, T. 37 N., R. 24 E.), the conglomerate also contains some volcanic rock clasts.

The Eocene sedimentary rocks at Bimetallic Mountain are chiefly sandstone and siltstone composed of broken crystals of quartz, feldspar, biotite, and hornblende (Fox, 1973, 1978).

Ev

Volcanic rocks, undivided (Eocene)--A variety of lava flows, pyroclastic rocks, hypabyssal intrusions, and minor sedimentary rocks that cannot be mapped separately at the 1:100,000 map scale. Several small, isolated outcrops of these Eocene rocks crop out between Carter Mountain and Fish

Lake, northeast of Conconully (T. 36 N., R. 25 and 26 E.) (Rinehart and Fox, 1976). Whole-rock, major-element geochemical analyses of several dikes from the two westernmost outcrops indicate compositions ranging from andesite to rhyolite (Table 2).

Metasedimentary and Metavolcanic Rocks

Mesozoic Metasedimentary and Metavolcanic Rocks

Jcg_e, Jmv_e

Ellemeham Formation (Jurassic)(?)--The Ellemeham Formation forms a discontinuous belt along the Okanogan and Similkameen River valleys, from Ellisforde (T. 38 N., R. 27 E.) to the Canadian border (Krauskopf, 1938; Fox, 1970; Rinehart and Fox, 1972). It consists of a basal unit of interbedded greenstone and metasiltstone (Jmv_e) and an upper unit of metaconglomerate (Jcg_e). The metaconglomerate is composed chiefly of greenstone and siltstone clasts derived from the lower unit, but it also contains metasedimentary and metavolcanic rock fragments derived from still older rock units. The maximum thickness of the Ellemeham Formation is approximately 915 m (Rinehart and Fox, 1972).

The Ellemeham Formation unconformably overlies tightly folded, upper greenschist-facies metasedimentary and metavolcanic rocks of the Kobau Formation and Anarchist Group, but is itself restricted to the lower greenschist facies and is only moderately warped and tilted. It is intruded by the Shakers Bend alkalic complex. Fenitized (alkali metasomatized) greenstone in the Ellemeham Formation near the contact with the alkalic rocks has yielded a K-Ar biotite age of 157.4 ± 4.7 Ma (Engels and others, 1976) that represents the minimum age of the intrusion. The Shakers Bend alkalic complex is thought to be correlative with the alkalic border phase of the Similkameen pluton (170 Ma) (Rinehart and Fox, 1976) (Table 1). The above relations indicate that the Ellemeham Formation was deposited after metamorphism and folding of the Anarchist Group and Kobau Formation, but prior to intrusion of the alkalic rocks approximately 170 m.y. ago. A Late Triassic or Early Jurassic age is probable. The Ellemeham Formation may be coeval with the Rossland Group in the Republic 1:100,000-scale quadrangle and in southern British Columbia (Höy and Andrew, 1988, 1989; Stoffel, 1990).

Jcg_{oe}

Metaconglomerate--Angular clasts of greenstone and siltstone in a sandy matrix of similar composition. The clasts are generally less than 1 m across, but are locally much larger. They were derived from erosion of the lower part of the Ellemeham Formation. This basal metaconglomerate grades upward into metaconglomerate composed of angular to subrounded pebbles and cobbles of lower Ellemeham Formation greenstone and siltstone and a variety of metamorphic rocks derived from the Anarchist Group and Kobau Formation (Rinehart and Fox, 1972).

Jmv_e

Metavolcanic rocks--Interbedded massive greenstone and thinly laminated metasiltstone. Primary minerals and textures are only locally preserved in the aphanitic greenstone. Vesicles, amygdules, and crude pillow structures indicate some of the greenstone represents lava flows, but remnant clastic textures and crude bedding suggest that some of the greenstone was originally tuff. Feldspar laths and pyroxene grains as much as 6 mm long are preserved in places, but the greenstone is

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generally recrystallized and composed of quartz, albite, epidote/clinozoisite, tremolite/actinolite, biotite, chlorite, ilmenite, magnetite, and minor K-feldspar and muscovite (Rinehart and Fox, 1972). This mineral assemblage is characteristic of the lower greenschist facies. A weak schistosity is locally developed in the greenstone.

The lower part of the Ellemeham Formation metavolcanic unit contains a few thin lenses of metalimestone and hornblende-bearing metatuff. A thin layer of metaconglomerate composed of pebbles and cobbles derived from the Kobau Formation is present at the base of the unit at Shakers Bend.

R mm_x

Metamorphic complex of Conconully, phyllite and metasiltstone (Triassic)(?)--Phyllite and metasiltstone intercalated with thin, lenticular interbeds of quartzite, greenstone, and fine- to medium-grained metalimestone. The phyllite and metasiltstone are composed of quartz, biotite, and muscovite-sericite. Near younger intrusions the phyllite and metasiltstone have been thermally upgraded to schist and hornfels that contain garnet, andalusite, and sillimanite.

This unit is exposed along the North Fork Pine Creek (T. 36 and 37 N., R. 25 and 26 E.) and near Evans Lake (sec. 28, T. 35 N., R. 26 E.) (Goldsmith, 1952; Rinehart and Fox, 1976; Sims, 1984). The phyllite and metasiltstone in the metamorphic complex of Conconully apparently grade into amphibolite-facies rocks in the metamorphic complex of Conconully (pJhm_x), but the rocks in the gradational zone are poorly exposed in a valley filled with thick Quaternary deposits.

This phyllite and metasiltstone unit conformably overlies and interfingers(?) with the Late(?) Triassic Cave Mountain Formation, which suggests that at least part of the metamorphic complex of Conconully is Late Triassic in age (Rinehart and Fox, 1976).

R mv_c , R mm_c , R cb_c

Cave Mountain Formation (Triassic)--The Cave Mountain Formation, a folded and faulted 1,300-m-thick sequence of interbedded metalimestone, metadolomite, metasiltstone, slate, and metavolcanic rocks, covers approximately 80 km² along the southern border of the map area (Rinehart and Fox, 1976). The formation has been subdivided into five "distinctive and readily mappable members" (Rinehart and Fox, 1976, p. 9), but the distribution of these members is too complex to show at the 1:100,000 map scale. Therefore, the Cave Mountain Formation is herein subdivided into only three map units: R mv_c , metavolcanic rocks; R mm_c , metasedimentary rocks; and R cb_c , metacarbonate.

The Cave Mountain Formation is conformably overlain by and interfingers(?) with phyllite and metasiltstone in the metamorphic complex of Conconully. Near the contact with the Paleozoic metasedimentary rocks near Booher Lake (Pzmm) (T. 35 N., R. 26 E.), the Cave Mountain Formation contains lenses of magnesitic metadolomite and sheared and brecciated serpentinite. The metadolomite is a distinctive rock that contains magnesite and disseminated flakes of bright green fuchsite, a chromium-rich variety of muscovite. The greenish-gray, mottled serpentinite is composed of antigorite and minor carbonate, talc, tremolite, chlorite, and chromite. Rinehart and Fox (1976) believe that the magnesitic metadolomite is sedimentary in origin. They think that the serpentinite formed by alteration of the magnesitic rocks. E. S. Cheney (University of Washington, written commun., 1990) believes that the magnesitic rocks formed by alteration of serpentinite. He thinks that the bodies of serpentinite and magnesitic rocks lie along a thrust fault that separates the Cave Mountain Formation from the underlying Paleozoic metasedimentary rocks.

Late(?) Triassic pelecypods and an ammonite have been recovered from the Cave Mountain Formation near Alkali Lake (sec. 22, T. 35 N., R. 26 E.) (Waters and Krauskopf, 1941; Misch, 1966; Rinehart and Fox, 1976). The Cave Mountain Formation is temporally correlative with part of the Nicola Group in southern British Columbia (Read and Okulitch, 1977; Tempelman-Kluit, 1989).

Tr mv_c

Metavolcanic rocks--Gray to olive-gray metabasalt and metabasalt breccia; 300 m thick. The metabasalt is typically blastoporphyritic. It is composed of black, equant hornblende crystals, 1- to 5-mm across, in an olive-gray, fine-grained, carbonate-rich matrix. The hornblende is pseudomorphic, probably after pyroxene. Amygdules filled with feldspar, calcite, and actinolite indicate that some of the metabasalt represents lava flows. The metabasalt breccia contains small to large bombs, lapilli, and fine-grained volcanic rocks in a schistose, carbonate-rich matrix. It is clearly pyroclastic in origin.

Tr mm_c

Metasedimentary rocks--Metasiltstone and phyllite, with subordinate interbeds of metasandstone and metalimestone. Principal constituents of the thinly laminated, dark-gray metasiltstone and phyllite are quartz, biotite, calcite, and muscovite. Most of the metasiltstone and phyllite are characterized by granoblastic textures, but relict clastic textures are locally preserved. The metalimestone is typically silty or phyllitic.

Tr cb_c

Metacarbonate--Massive white, blue-gray, and pale yellow-brown, medium- to coarse-grained metalimestone and metadolomite with thin beds of silty metalimestone, quartzose metasandstone, and metaconglomerate. The metaconglomerate consists of rounded to angular pebbles of chert and quartzite, as much as 15 mm across, in a sandy dolomitic matrix.

Calcite and dolomite are the principal constituents of the recrystallized metalimestone and metadolomite. Tremolite, diopside, and scapolite commonly form porphyroblasts as much as 6 mm long. Brucite, garnet, serpentine, and chlorite are minor components. Chert nodules, 2 to 5 cm long, are sporadically distributed throughout the metacarbonate.

Tr Rmmt_k

Kobau Formation (Triassic or Permian)(?)--A layered sequence of phyllite, greenstone, and quartzite (metachert). The unit forms a broad, discontinuous belt along the Canadian border between Chopaka Mountain (T. 40 N., R. 25 E.) and Chesaw (T. 40 N., R. 30 E.) (Rinehart and Fox, 1972; Fox, 1970, 1978). The Kobau Formation is approximately 650 m thick on Ellemeham Mountain northeast of Palmer Lake (Rinehart and Fox, 1972).

Along the Canadian border, the Kobau Formation consists of grayish-green phyllite and subordinate quartzite, greenstone, and metalimestone. The black and bluish-gray quartzite consists chiefly of fine-grained quartz, with minor actinolite, mica, and other metamorphic minerals. It is thought to have formed by recrystallization of chert, not clastic quartzose sandstone (Rinehart and Fox, 1972). The thinly layered to massive greenstone is generally aphanitic, but is locally porphyritic. Metalimestone layers are typically fine-grained and dolomitic.

The Kobau Formation(?) also form isolated outcrops on the southern end of Duffys Mountain (T. 37 N., R. 27 E.), along the southwest side of Cayuse Mountain (T. 37 N., R. 26 E.), and 3 km southwest of Janis (sec. 12, T. 36 N., R. 26 E.) (Rinehart and Fox, 1976; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1989). At these localities, the formation consists of interbedded greenish-gray phyllite, greenstone, amphibolite, and minor massive light-gray metadolomite and metalimestone with sparse chert nodules. The amphibolite and greenstone are weakly foliated to directionless, fine- to medium-grained rocks composed chiefly of actinolite and chlorite. They generally form concordant layers a few tens of meters thick, but also occur as discontinuous, irregularly shaped masses (Rinehart and Fox, 1976). The fine-grained greenstone probably represents lava flows and pyroclastic rocks, and the medium-grained amphibolite may represent hypabyssal intrusions (Rinehart and Fox, 1976).

Magnesitic metadolomite and serpentinite form discontinuous lenses in the Kobau Formation along the Similkameen River (sec. 18, T. 40 N., R. 27 E.) (Fox and Rinehart, 1968; Rinehart and Fox, 1972) and east of Chesaw (Fox, 1970; McMillen, 1979). Fox and Rinehart (1968) believe that the magnesitic rocks are sedimentary in origin. They think that the serpentinite formed by alteration of the magnesitic rocks. McMillen (1979), Cheney and others (1982), and Orr and Cheney (1987) believe that the magnesitic rocks formed by alteration of serpentinite. They think that the magnesitic rocks and serpentinite lie along a regional thrust fault that separates the Kobau Formation from the Anarchist Group.

The Kobau Formation is equivalent to the Kobau Group in southern British Columbia (Bostock, 1940; Tempelman-Kluit, 1989). It is intruded by the Similkameen and Loomis plutons and by the Late Triassic orthogneiss of Osoyoos. The Kobau Formation conformably overlies, grades into, and is locally intruded by the Palmer Mountain Greenstone. It is unconformably overlain by the Ellemeham Formation, which is probably Early Jurassic in age. Rinehart and Fox (1972) thought that the Kobau Formation unconformably overlies the Permian Anarchist Group. McMillen (1979), Cheney and others (1982), and Orr and Cheney (1987) believe that the contact between the two units is marked by a regional thrust fault. Because no fossils have been recovered from the Kobau Formation, and because the nature of the contact between the Kobau Formation and the Anarchist Group is uncertain, the age of the Kobau Formation is unknown. However, because it is intruded by the orthogneiss of Osoyoos (200 Ma), the Kobau Formation must be Triassic or older.

TRM_{mv}

Palmer Mountain Greenstone (Triassic or Permian)(?)--Greenstone and minor metadiabase are composed of a variety of metamorphic minerals indicative of greenschist-facies metamorphism. The principal constituents are hornblende/actinolite, albite/oligoclase, epidote/clinozoisite, chlorite, biotite, sericite, calcite, and minor quartz and K-feldspar. Common accessory minerals include apatite, ilmenite, and magnetite. Some of the amphibole grains are cored with clinopyroxene, and many of the grains are pseudomorphous after pyroxene. The original composition of the greenstone and metadiabase probably ranged from dacite to basalt (Rinehart and Fox, 1972). Massive sulfides form stratiform layers in places.

Although most of the rocks have been metamorphosed, relict textures are locally well preserved. They indicate that the greenstone was originally massive, fine grained, and aphanitic, and the metadiabase was massive, medium grained, and diabasic. Relict vesicles and felty textures indicate that much of the greenstone represents lava flows. The metadiabase probably represents hypabyssal intrusions.

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The Palmer Mountain Greenstone is a 2,135-m-thick assemblage of greenstone and metadiabase that forms most of Palmer Mountain (T. 39 N., R. 26 E.) and the northwest flank of Bullfrog Mountain (T. 40 N., R. 26 E.) (Rinehart and Fox, 1972). The Palmer Mountain Greenstone interfingers with, grades into, and locally intrudes the Kobau Formation. It is thought to be the extrusive or near surface equivalent of the Chopaka intrusive complex (R_{Pmib_c} , R_{Pmu_d}). Rinehart and Fox (1972) thought that the Palmer Mountain Greenstone unconformably overlies the Bullfrog Mountain Formation (Anarchist Group). E. S. Cheney (University of Washington, written commun., 1990) believes that the Palmer Mountain Greenstone and the Chopaka intrusive complex represent an ophiolite complex that lies along a regional thrust fault that separates them from the Anarchist Group.

Amphibolite in the Chopaka intrusive complex has yielded a K-Ar actinolitic hornblende age of 190.5 ± 15.6 Ma (Hibbard, 1971) that represents the metamorphic age of the complex and not the magmatic crystallization age. This radiometric age and the observed stratigraphic relations suggest that the Palmer Mountain Greenstone is Triassic or older. It is probably correlative with the Old Tom Formation in southern British Columbia (Bostock, 1940; Tempelman-Kluit, 1989).

Paleozoic Metasedimentary and Metavolcanic Rocks

R_{mm_b} , R_{mm_s} , $R_{mc_b_s}$, R_{mmv_s} , R_{mm_a} , $R_{mc_b_a}$

Anarchist Group (Permian)--The Anarchist Group consists of two formations, the Spectacle and Bullfrog Mountain Formations (Rinehart and Fox, 1972). Phyllite, slate, metawacke, and chert-pebble metaconglomerate are the principal constituents of both formations. The Spectacle Formation also contains metalimestone and minor greenstone.

Permian brachiopods, pelecypods, gastropods, corals, and crinoid columnals have been recovered from the Spectacle Formation at several localities in the map area (Rinehart and Fox, 1972, 1976; McMillen, 1979). The Anarchist Group is correlative with the Cache Creek Group in southern British Columbia (Read and Okulitch, 1977).

Rinehart and Fox (1972) thought that the Anarchist Group is unconformably overlain by the Kobau Formation and Palmer Mountain Greenstone. McMillen (1979), Cheney and others (1982), and Orr and Cheney (1987) believe that the Anarchist Group is separated from those units by a regional thrust fault.

R_{mm_b}

Bullfrog Mountain Formation--Chiefly black slate and phyllite intercalated with massive pale greenish-gray metawacke and metaconglomerate (Fox, 1970; Rinehart and Fox, 1972). The metaconglomerate, which forms beds as much as 60 m thick, is composed of angular clasts of dark-gray chert, slate, metasiltstone, metavolcanic rocks, and rare metalimestone, in a poorly sorted, sandy matrix.

The Bullfrog Mountain Formation is approximately 1,525 m thick at its type locality on Bullfrog Mountain (T. 40 N., R. 26 E.) (Rinehart and Fox, 1972). It thickens to the south and thins to the northeast.

The Bullfrog Mountain Formation overlies the Spectacle Formation. No fossils have been found in the Bullfrog Mountain Formation, but because it is compositionally similar to and grades downward into the Permian Spectacle Formation the age of the Bullfrog Mountain Formation is thought to be Permian.

$\text{R}_{\text{m}}\text{mm}_s$, $\text{R}_{\text{mc}}\text{b}_s$, $\text{R}_{\text{m}}\text{mv}_s$

Spectacle Formation--Slate, phyllite, and metasiltstone interbedded with metawacke, metaconglomerate, metalimestone, and minor greenstone (Fox, 1970, 1978; Rinehart and Fox, 1972). Metaconglomerate and metalimestone are restricted to the upper two-thirds of the formation. Greenstone is present only in the lower third. Because it is intensely folded and faulted, the true thickness of the Spectacle Formation is impossible to ascertain. The thickest measured section is 4,500 m (Rinehart and Fox, 1972).

Black slate and green phyllite are the chief constituents of the Spectacle Formation. Foliation is typically, but not everywhere parallel to bedding. It is locally so strongly developed that primary sedimentary textures have been obliterated. Metasiltstone, metawacke, and metaconglomerate in the Spectacle Formation are massive to thinly laminated rocks that are distinctly less deformed than the slate and phyllite. The metaconglomerate is widely distributed throughout the formation, but it constitutes only a small percentage of the unit. The metaconglomerate consists of angular to subrounded clasts of dark-gray chert in a light-gray, poorly sorted, sandy matrix.

Metalimestone ($\text{R}_{\text{mc}}\text{b}_s$) forms lenticular or pod-like masses in the Spectacle Formation. It is generally between 30 and 45 m thick, but is locally as much as 750 m thick (Rinehart and Fox, 1972; McMillen, 1979). The metalimestone is fine grained, thinly laminated, and commonly contorted. It is composed chiefly of calcite, but it locally contains sandy, cherty, shaly, or graphitic zones.

Greenstone and amphibolite bodies in the Spectacle Formation ($\text{R}_{\text{m}}\text{mv}_s$) that are large enough to show at the 1:100,000 map scale are present only along the Okanogan River valley near Ellisforde (sec. 14, T. 38 N., R. 27 E.). They probably represent metamorphosed pyroclastic rocks, lava flows, and hypabyssal intrusions.

Brachiopod, pelecypod, and gastropod molds have been recovered from massive, fine- to coarse-grained, calcareous metawacke in the upper part of the Spectacle Formation at several localities. J. T. Dutro, Jr., and E. L. Yochelson (USGS) identified the brachiopods as *Megousia* and *Yakovlevia*(?) (Rinehart and Fox, 1972). They believe that the fossils are Permian in age, possibly early Late Permian. Phyllite in the Spectacle Formation on Buckhorn Mountain (sec. 27, T. 40 N., R. 30 E.) contains sheared and fragmented corals, identified by W. J. Sando (USGS) as *Caninia*, s. l. and *Heintzella*(?) sp. Sando (written commun., to K. F. Fox, Jr., 1979) believes that

"... the material is clearly upper Paleozoic. Mississippian is an unlikely possibility.

Middle or Upper Pennsylvanian or lower Permian is more probable. The lack of diagnostic Permian forms may give slightly more credence to a Pennsylvanian age" (McMillen, 1979, p. 6).

$\text{R}_{\text{m}}\text{mm}_a$, $\text{R}_{\text{mc}}\text{b}_a$

Anarchist Group, undivided--Phyllite and quartzite intercalated with thin, discontinuous lenses of chert-pebble metaconglomerate, metalimestone, and greenstone. These rocks form a northwest-trending belt along the West Fork Sanpoil River in the southeastern corner of the Oroville 1:100,000-scale quadrangle and the southwestern corner of the Republic 1:100,000-scale quadrangle (Rinehart and Greene, 1988; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988). No fossils have been recovered from these metasedimentary rocks, but C. D. Rinehart and K. F. Fox, Jr., (USGS, written commun., 1988) believe that they are correlative with the Anarchist Group because they contain chert-pebble metaconglomerate and blue quartzite, which are distinctive lithologies in the Anarchist Group.

Rinehart and Greene (1988) believe that these greenschist-facies metasedimentary rocks grade into amphibolite-facies metamorphic rocks that are probably thermally upgraded Anarchist Group metasediments. Cheney and others (1982), Orr (1985), and Orr and Cheney (1987) think that the contact between the greenschist-facies and amphibolite-facies rocks is abrupt and probably marked by a fault. They believe that the amphibolite-facies rocks are part of the Okanogan metamorphic core complex.

Pzmm

Metasedimentary rocks near Tonasket and Booher Lake (Paleozoic)(?)--Metasedimentary rocks composed of granitic and metamorphic rock detritus crop out on the southern end of Cayuse Mountain near Tonasket and on the west side of Wagonroad Coulee between Booher and Medicine Lakes (T. 35 N., R. 26 E.). The metasedimentary rocks near Tonasket consist of greenish-gray metawacke and meta-arkose with thin interbeds of black slate and phyllite. The massive metawacke and meta-arkose are composed of angular grains of quartz, microcline, albite, and muscovite, and angular clasts of quartzite and granite in a fine-grained matrix of sericite and/or chlorite (K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). Most of the metasedimentary rocks near Tonasket are phyllitic, and some have been intensely sheared and reduced to cataclasites composed of equant to lenticular quartz grains dispersed throughout a phyllitic matrix (Rinehart and Fox, 1976). The metasedimentary rocks near Booher Lake consist of metaconglomerate with minor interbeds of metawacke, orthoquartzite, and phyllitic metasiltstone (Rinehart and Fox, 1976). The metaconglomerate is composed of quartzite clasts in a greenish-gray matrix rich in fuchsite (a chromium-bearing mica).

Near Booher Lake, small bodies of serpentinite and magnesitic metadolomite lie near the contact between these metasedimentary rocks and the Cave Mountain Formation. West of Tonasket, a discontinuous body of magnesitic metadolomite crops out near the contact between these rocks and the Kobau Formation. Rinehart and Fox (1976) believe that the magnesitic rocks are sedimentary in origin, and think that the serpentinite formed by alteration of the magnesitic rocks. E. S. Cheney (University of Washington, written commun., 1990) believes that the magnesitic rocks formed by alteration of serpentinite. He thinks that the serpentinite and magnesitic rocks lie along a regional thrust fault that separates the Paleozoic metasedimentary rocks from the Cave Mountain and Kobau Formations.

No fossils have been recovered from these metasedimentary rocks, which were originally assigned to the Permian Anarchist Group (Fox, 1970; Rinehart and Fox, 1972, 1976; Fox and Rinehart, 1972). The arkosic composition of the rocks suggest that they may be correlative with the Ordovician(?) Covada Group on the Nespelem and Republic 1:100,000-scale quadrangles to the east (Fox and Rinehart, 1974; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988), but because this correlation is uncertain, a Paleozoic age is tentatively assigned.

Intrusive Igneous Rocks

Tertiary Intrusive Igneous Rocks

Tertiary Hypabyssal Intrusive Rocks

Eian_o

Augite trachyandesite plugs near Oroville (Eocene)--Massive, olive-gray to brownish-black, and porphyritic trachyandesite that consists of 1- to 3-mm-long augite and andesine phenocrysts in a microcrystalline groundmass of augite, andesine, and minor sanidine, biotite, apatite, and magnetite. The augite phenocrysts commonly form clots (glomerocrysts) in the rocks.

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Two small plugs of this trachyandesite crop out in the hills northeast of Oroville (Fox, 1970, 1973). The plugs cut the Oroville alkalic complex and Eocene conglomerate composed of alkalic rock clasts derived from the complex. They are compositionally similar to sills and dikes that cut Klondike Mountain Formation sedimentary rocks in the Republic 1:100,000-scale quadrangle. They may be the intrusive equivalent of flows in the upper part of the Klondike Mountain Formation (Stoffel, 1990).

Eida, Eian, ++++++

Porphyritic dacite and andesite plugs and dikes (Eocene)--Euhedral plagioclase (andesine-oligoclase) and subhedral hornblende phenocrysts in an aphanitic to fine-grained holocrystalline groundmass of plagioclase, quartz, and K-feldspar. Minor biotite, augite, and quartz phenocrysts are present locally. Apatite and magnetite are common accessory minerals. Mafic minerals are commonly replaced by secondary calcite and chlorite.

Plugs and dikes of porphyritic dacite (Eida) and andesite (Eian) are widespread in the map area. K-Ar hornblende ages of 51.4 ± 2.6 Ma and 52.1 ± 2.3 Ma are reported from the plugs west of Oroville (Rinehart and Fox, 1972). These ages are the same as ages reported from porphyritic dacite and andesite intrusions in the Republic 1:100,000-scale quadrangle (Stoffel, 1990).

Eid

Diorite plugs (Eocene)--Massive, dark greenish-gray, fine- to medium-grained diorite and quartz diorite composed of plagioclase, hornblende, and varied amounts of quartz. Biotite, K-feldspar, sphene, and apatite are common accessory minerals.

The diorite forms several small plugs near Sinlahekin Creek (T. 37 N., R. 24 E.) (DGER unpublished mapping) and northeast of Havillah (T. 39 N., R. 29 E.) (Fox, 1978). They intrude Eocene tuff and tuff breccia. The plugs near Havillah cut Spectacle Formation (Anarchist Group) metasedimentary rocks. All these diorite plugs are probably of Eocene age.

Tertiary Plutonic Rocks

Early Tertiary plutonic rocks make up hundreds of square kilometers in the Okanogan highlands of northeastern Washington. These plutonic rocks have been subdivided into three intrusive suites, the Keller Butte, Devils Elbow, and Herron Creek suites (Holder and Holder, 1988; Holder and others, 1989). Tertiary plutons in the map area include the Swimpotkin Creek pluton (Devils Elbow suite) and the Moses and Mount Bonaparte plutons (Keller Butte suite). Herron Creek suite intrusions are not found in the map area.

Radiometric ages indicate that the three intrusive suites were emplaced in the early Tertiary. K-Ar biotite ages ranging from 61 to 49 Ma are reported from the Keller Butte suite plutons, suggesting intrusion in the Paleocene and early Eocene(?). K-Ar biotite and hornblende ages between 53 and 45 Ma have been obtained from Devils Elbow and Herron Creek suite plutons, indicating early to middle Eocene emplacement. Intrusion of the Devils Elbow and Herron Creek suites was largely coeval, and they probably are comagmatic with the Sanpoil Volcanics and with rhyolite domes that intrude the Sanpoil Volcanics (Holder and Holder, 1988; Holder and others, 1989). The relation between Keller Butte suite plutons and the Eocene volcanic rocks is unclear.

Structural relations among the Tertiary plutonic rocks, Eocene volcanic and sedimentary rocks, and amphibolite-facies metamorphic rocks in the Okanogan metamorphic core complex indicate that emplacement of the plutons occurred during regional extension and was broadly contemporaneous with volcanism and the formation of metamorphic core complexes and tectonic depressions (Holder and Holder, 1988; Parrish and others, 1988; Holder and others, 1989).

Eimds_s

Swimptkin Creek pluton (Eocene)--Gray, medium- to coarse-grained, equigranular quartz monzodiorite. Average composition is 50 percent plagioclase, 20 percent K-feldspar, 15 percent quartz, and 15 percent hornblende and biotite (Gulick, 1987). Some of the hornblende crystals contain pyroxene cores. Accessory minerals include sphene, apatite, and magnetite.

The Swimptkin Creek pluton is weakly lineated and foliated in places. The north-northwest-trending lineation is defined by the alignment of tabular hornblende crystals. It is parallel to the prominent lineation in the metamorphic rocks of the Okanogan metamorphic core complex. The southwestern margin of the Swimptkin Creek pluton in the Omak 1:100,000-scale quadrangle has been cataastically deformed along with the gneissic rocks that it intrudes.

The Swimptkin Creek pluton forms several intrusions in the southeastern corner of the map area (Cheney and others, 1982; Orr and Cheney, 1987; Gulick, 1987). These rocks form the northern margin of the Swimptkin Creek pluton, which covers approximately 100 km² in the Omak 1:100,000-scale quadrangle to the south (Fox and others, 1976; Atwater and Rinehart, 1984; Holder and Holder, 1988; Holder and others, 1989). It intrudes the Tonasket Gneiss and the Crawfish Lake tonalite gneiss in the Okanogan metamorphic core complex. It contains inclusions and roof pendants of hornblende gabbro, diorite, mylonitic gneiss, and fine-grained hornfels. K-Ar hornblende and biotite ages from the Swimptkin Creek pluton are about 49 Ma, "...except for a hornblende age of 45 m.y. that is probably erroneous..." (Atwater and Rinehart, 1984, p. 4).

EP ia_m

Moses pluton (Eocene or Paleocene)--Gray, medium- to coarse-grained, leucocratic (color index <5) granite and granodiorite. Biotite is the only mafic mineral; muscovite (both primary and secondary) is a common accessory. Some of the rocks are equigranular, and some are porphyritic. The latter are composed of 1- to 2-cm-long K-feldspar phenocrysts in a medium- to coarse-grained groundmass. Pegmatitic and aplitic alaskite dikes, pods, and irregular masses cut the granite and granodiorite in places. They contain abundant euhedral pink and red garnet crystals. Xenoliths and pendants of cataastically deformed gneiss and hornfels are also common in the granite and granodiorite.

Much of the Moses pluton is massive, but it is weakly to moderately foliated and lineated in places, particularly along its western border. The lineation generally strikes northwest, parallel to the lineation in the Tonasket Gneiss.

The Moses pluton occupies the southeastern corner of the map area and extends south and east into the adjacent Omak, Nespelem, and Republic 1:100,000-scale quadrangles (Atwater and Rinehart, 1984; Singer, 1984; Gulick, 1987; Holder and Holder, 1988; Holder and others, 1989). The Moses pluton intrudes the Tonasket Gneiss. Contact relations between the Moses and Swimptkin Creek plutons are ambiguous (Singer, 1984; Gulick, 1987). In some places, the Moses pluton appears to cut the Swimptkin Creek pluton, but in other places the reverse is true. Locally, the contact between the two plutons is marked by a swirled zone. K-Ar biotite ages of 47.8 ± 1.2 Ma and 49.4 ± 1.2 Ma are reported from the Moses pluton in the Omak 1:100,000-scale quadrangle (Atwater and Rinehart, 1984).

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However, because other Keller Butte suite plutons in the region have yielded Paleocene radiometric ages, the K-Ar biotite ages reported for the Moses pluton must be considered minimum ages.

EPA ia_b, EPA id_b, EPA ip_b

Mount Bonaparte pluton (Eocene or Paleocene)--A zoned pluton which consists of porphyritic, medium- to coarse-grained leucocratic granodiorite and granite that grades outward into equigranular, fine- to medium-grained, leucocratic granodiorite. Principal constituents of the equigranular rocks are oligoclase, orthoclase, and quartz. Biotite, the only mafic mineral, forms less than 5 percent of the rocks. Allanite and apatite are common accessory minerals. The porphyritic rocks are composed of tabular K-feldspar phenocrysts, as much as 3 cm long, in a medium- to coarse-grained groundmass of plagioclase, K-feldspar, and quartz.

Mesocratic diorite (EPA id_b) forms a narrow border phase along the western margin of the Mount Bonaparte pluton near Wildhorse Spring (sec. 24, T. 39 N., R. 27 E.) and Havillah (sec. 7, T. 38 N., R. 29 E.) (Krauskopf, 1938; Fox, 1970, 1978; Cheney and others, 1982; Orr and Cheney, 1987). Principal constituents of the dark greenish-gray, medium- to coarse-grained diorite are plagioclase (andesine), biotite, and hornblende. Quartz, apatite, magnetite, and allanite are common accessory minerals.

Numerous dikes, pods, and irregular masses of pegmatite and alaskite (EPA ip_b) cut the granite and granodiorite of the Mount Bonaparte pluton, particularly along the northeastern border of the pluton. Widths of the pegmatite-alaskite bodies range from less than 1 cm to more than 100 m. Most of the dikes are too small to show at the 1:100,000 map scale, but the large masses southeast of Bonaparte Lake (T. 38 N., R. 30 E.) are shown (Fox, 1978).

Much of the Mount Bonaparte pluton is directionless to weakly foliated and lineated, but the southwestern margin is strongly gneissic. The foliation and lineation generally strike northwest, parallel to the structural fabric in the Tonasket Gneiss. They are the result of penetrative deformation of the pluton during formation of the Okanogan metamorphic core complex. Thus, the pluton is pre- or synkinematic with respect to the formation of the core complex.

The Mount Bonaparte pluton is a broad, northwest-trending intrusion between Oroville and Wauconda (T. 37 N., R. 30 E.) that extends east into the Republic 1:100,000-scale quadrangle (Fox, 1970, 1978; Cheney and others, 1982; Orr and Cheney, 1987; Holder and Holder, 1988; Rinehart and Greene, 1988; Holder and others, 1989; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988). The Mount Bonaparte pluton and its associated pegmatite-alaskite bodies intrude the Tonasket Gneiss, Anarchist Group, and the monzonitic and syenitic gneiss (pTgn). Fission-track and K-Ar ages from the Mount Bonaparte pluton range from 49 to 59 Ma (Table 1) and suggest that emplacement of the pluton occurred at some time during the Paleocene and early Eocene (Holder and Holder, 1988; Holder and others, 1989).

Tertiary or Mesozoic Intrusive Igneous Rocks

TKik

Alkalic intrusive complexes at Oroville and Bimetallic Mountain (Tertiary or Cretaceous)--Malignite, shonkinitite, foyaite, and monzonite. Dark grayish green to bluish-gray, fine- to coarse-grained malignite and shonkinitite are the most abundant lithologies in the complexes. Principal constituents of these rocks

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are perthitic orthoclase, nepheline, sodalite(?), plagioclase (oligoclase-andesine), hastingsite, and aegerine-augite or augite. Garnet, biotite, sphene, apatite, and magnetite are common accessory minerals. Mafic minerals form 30 to 50 percent of the rocks. At Oroville, the malignite and shonkinite grade into light bluish gray, fine-grained foyaite, composed of K-feldspar and subordinate plagioclase, nepheline, aegerine-augite, and hastingsite. Massive, grayish-pink, porphyritic monzonite intrudes the malignite, shonkinite, and foyaite in both complexes. It consists of tabular phenocrysts of perthitic orthoclase, as much as 6 cm long, in a fine- to medium-grained groundmass of plagioclase, chlorite, augite, hornblende, and accessory sphene, apatite, magnetite, biotite, and quartz. The phenocrysts are locally strongly oriented, imparting a distinctive trachytoid texture to the monzonite. Dikes of brecciated mesocratic alkalic rocks cut the alkalic complex at Oroville, and thin dikes and irregular masses of brecciated, fine-grained alaskite intrude the alkalic rocks at Bimetallic Mountain.

The complexes are exposed near Oroville and on Bimetallic Mountain (T. 39 N., R. 29 E.) (Fox, 1970, 1973, 1978). Most of the alkalic rocks are shattered or brecciated, and some are strongly hydrothermally altered. Country rocks surrounding the complexes are brecciated and locally hornfelsed and fenitized (alkali metasomatized). Krauskopf (1941) thought that the intense brecciation of the rocks in the alkalic complexes occurred during intrusion of the nearby Okanogan metamorphic core complex. Fox (1973, p. 132) believed that the breccias are "primarily the products of internal processes related to the development of the alkalic complexes, and are not the products of crushing by the Okanogan gneiss dome."

The age(s) of the alkalic intrusive complexes at Oroville and Bimetallic Mountain is uncertain. The alkalic rocks at Oroville intrude the Spectacle, Kobau, and Ellemeham Formations, and the alkalic rocks at Bimetallic Mountain cut the Spectacle and Kobau Formations. Both complexes are locally overlain by sedimentary rocks that include conglomerate and arkose composed of malignite, shonkinite, monzonite, and alaskite clasts derived from the complexes. Eocene fossil leaves have been found in these sedimentary rocks at Oroville (Fox, 1973). Small plugs of augite trachyandesite cut the alkalic rocks at Oroville, and porphyritic felsite dikes cut the alkalic rocks at Bimetallic Mountain. The plugs and dikes are probably Eocene in age. These stratigraphic relations suggest that the age of the alkalic complexes at Oroville and Bimetallic Mountain is early Tertiary or Cretaceous.

Mesozoic Intrusive Igneous Rocks

Mzi, + + +

Mesozoic dikes, sills, and plugs--Dikes, sills, and plugs of acidic and intermediate composition. Most of these hypabyssal intrusive rocks are porphyritic. They are composed of feldspar and/or quartz phenocrysts in fine-grained to aphanitic groundmasses of quartz, feldspar, and mafic minerals. The rocks are hydrothermally altered and mineralized in places. Some have been metamorphosed along with the country rocks that they intrude.

These dikes, sills, and plugs are widespread in the map area (Fox, 1970, 1978; Rinehart and Fox, 1972, 1976). They intrude the Anarchist Group, Kobau Formation, Palmer Mountain Greenstone, and the metamorphic complex of Conconully. The cross-cutting relations suggest that most of the intrusions are post-middle Permian in age. They may represent more than one Mesozoic intrusive event.

Mzia

Mesozoic acidic intrusive rocks--Several small masses of fine- to medium-grained quartz monzonite and granodiorite. Pegmatite and alaskite pods and dikes are associated with several of these intrusions. The rocks near Ellisforde, assigned to the Ellisforde pluton by Fox (1970), are crushed and brecciated in places.

These rocks are exposed near Myers Creek in the northeastern corner of the quadrangle (Fox, 1978), along the Okanogan River valley near Ellisforde (T. 38 N., R. 27 E.) (Woodward, 1936; Fox, 1970), and near Mud Lake (sec. 24, T. 36 N., R. 25 E.) (Rinehart and Fox, 1976). The quartz monzonite and granodiorite near Myers Creek and Ellisforde cut the Anarchist Group. The intrusion at Mud Lake cuts the metamorphic complex of Conconully. Little can be said about the age of these intrusions except that they are probably Mesozoic. They may represent more than one intrusive event.

Kigd_c

Conconully pluton (Cretaceous)--Leucocratic, equigranular to porphyritic, medium- to coarse-grained granodiorite and quartz monzonite. The rocks are composed of plagioclase, quartz, K-feldspar, biotite, and minor hornblende. Common accessory minerals include magnetite, apatite, sphene, and zircon. Mafic minerals generally form less than 10 percent of the rocks.

Plagioclase is the most abundant constituent in the equigranular rocks. It forms subhedral to anhedral grains with andesine cores and oligoclase rims. Quartz and K-feldspar occur as anhedral to subhedral grains interstitial to the plagioclase. The K-feldspar is chiefly microperthitic microcline. The equigranular rocks grade into porphyritic rocks composed of pink K-feldspar phenocrysts, as much as 5 cm long, in a medium- to coarse-grained groundmass very similar to in composition to the equigranular rocks.

The Conconully pluton is a 200-km² intrusion that straddles the border between the Oroville and Omak 1:100,000-scale quadrangles near Conconully (Goldsmith, 1952; Menzer, 1964, 1983; Rinehart and Fox, 1976; Rinehart, 1981). The eastern border of the Conconully pluton is hydrothermally altered and mineralized in places, particularly near the town of Conconully. Secondary minerals include sericite, saussuritic pistacite, clinozoisite, chlorite, and pyrite.

The Conconully pluton and dikes emanating from it intrude the metamorphic complex of Conconully, the Leader Mountain granodioritic gneiss, and the Tiffany complex. Contacts are generally sharp and discordant, and intrusion breccias are locally developed, but contacts between the pluton and the Tiffany complex are locally gradational.

Menzer (1970) reported the following radiometric ages for the Conconully pluton:

90 ± 20 Ma	lead-alpha (zircon)
89 ± 9 Ma	fission-track (apatite)
84 ± 8 Ma	fission-track (sphene)
81.1 ± 0.8 Ma	Rb-Sr (isochron)

Berry and others (1976) reported K-Ar hornblende and biotite ages of 81.2 ± 2.4 Ma and 78.8 ± 2.4 Ma, respectively. Rinehart and Fox (1976) reported K-Ar hornblende and biotite ages of 72.8 ± 4.6 Ma and 62.5 ± 2.2 Ma, respectively. The wide variation in ages

"... together with the discordance shown by the potassium-argon mineral ages, suggest that a younger thermal event, centered east of the pluton, may have reduced the apparent mineral ages in the eastern part of the pluton" (Rinehart and Fox, 1976, p. 38).

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Kia_e

Evans Lake pluton (Cretaceous)(?)--A central phase of medium- to coarse-grained porphyritic granodiorite and quartz monzonite that grades into a fine- to medium-grained border phase of gneissic granodiorite. The porphyritic phase is composed of abundant blocky to tabular microcline phenocrysts, as much as 5 cm long, in a medium- to coarse-grained groundmass of microcline, oligoclase, quartz, biotite, and accessory ferrohastingsite, hornblende, epidote, sphene, allanite, and tourmaline. The border phase granodiorite is fine to medium grained and equigranular. It is similar in composition to the groundmass of the porphyritic phase, except that it contains less biotite. The border phase granodiorite locally grades into fine- to medium-grained diorite, composed chiefly of plagioclase (calcic oligoclase or andesine), hornblende, biotite, and microcline. The diorite contains minor interstitial quartz and orthoclase and accessory myrmekite, sphene, epidote, and allanite. Dikes of the porphyritic phase cut rocks of the border phase, indicating the latter is older.

The Evans Lake pluton is an 18 km², northwest-trending intrusion that straddles the border between the Oroville and Omak 1:100,000-scale quadrangles near Riverside (Grose, 1949; Rinehart and Fox, 1976; Sims, 1984). The pluton intrudes the Cave Mountain Formation and phyllite and metasiltstone in the metamorphic complex of Conconully. The contact along the northeastern border of the pluton is sharp and concordant with the southwest-dipping foliation in the metasedimentary rocks (Rinehart and Fox, 1976). Contacts elsewhere are generally sharp, but are locally gradational. Bent plagioclase twin lamellae and blastomylonitic textures in the border phase granodiorite on the south side of the intrusion indicate that the Evans Lake pluton was cataastically deformed and recrystallized after magmatic crystallization (Sims, 1984).

A K-Ar biotite age of 88.8 ± 2.8 Ma is reported from the Evans Lake pluton in the Omak 1:100,000-scale quadrangle (Rinehart and Fox, 1976). Because hornblende in the pluton is too altered to date, the biotite age should be considered a minimum age.

Kia_c

Cathedral batholith (Cretaceous)--Directionless, pinkish-gray, medium- to coarse-grained, leucocratic granodiorite and quartz monzonite. Principal constituents are plagioclase (oligoclase), perthitic K-feldspar, and quartz. Euhedral biotite crystals, as much as 2 mm in diameter, are ubiquitous but rarely exceed 10 percent of the rocks. Hornblende is minor. Accessory minerals include sphene, zircon, apatite, magnetite, wolframite, pyrite, and rutile. K-feldspar megacrysts, large glomerocrysts of quartz, and oval- to disk-shaped clots of mafic minerals are characteristic features of the Cathedral batholith. Mirolitic cavities and vugs filled with euhedral quartz crystals are present locally. Leucocratic pegmatite and aplite dikes cut the granodiorite and quartz monzonite in places.

The Cathedral batholith is a broad, northwest-trending intrusion that occupies nearly 500 km² in the northwestern corner of the Oroville 1:100,000-scale quadrangle, the northeastern corner of the Robinson Mtn. 1:100,000-scale quadrangle, and southern British Columbia (Daly, 1912; Goldsmith, 1952; Hibbard, 1962, 1971; Hawkins, 1963, 1968; Rinehart, 1981; J. W. H. Monger, Geological Survey of Canada, written commun., 1988). The Cathedral batholith intrudes the Tillman Mountain tonalitic gneiss and the gneissic trondhjemite of Tiffany Mountain. Sharp contacts generally separate the batholith from the country rocks along the eastern border of the intrusion (Hibbard, 1962), but gradational contacts are more characteristic of the western border (Hawkins, 1963). The Cathedral batholith has yielded K-Ar biotite ages of 94.0 ± 2.8 Ma (Hawkins, 1968) and 97.7 ± 2.9 Ma (Berry and others, 1976).

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Kia_b

Bottle Spring pluton (Cretaceous)--Granodiorite in the south, grading to quartz monzonite in the north. The rocks are directionless, equigranular, and medium grained. They are composed of plagioclase (sodic andesine to oligoclase), K-feldspar, quartz, biotite, minor hornblende, and accessory sphene. The color index of the rocks ranges from 7 to 25 and averages approximately 14.

The Bottle Spring pluton is a 25-km², northwest-trending intrusion in the west-central part of the map area (Goldsmith, 1952; Hibbard, 1971; Rinehart, 1981). The pluton intrudes the Tillman Mountain tonalitic gneiss, the gneissic trondhjemite of Tiffany Mountain, and the Tiffany complex. Contacts between the pluton and the Tillman Mountain tonalitic gneiss on the east are generally sharp and discordant, but narrow migmatitic zones are developed in places. The pluton is also discordant with the Tiffany complex on the south, truncating structures in the complex. The contact between the Bottle Spring pluton and the Lone Frank pluton is marked by a shear zone (Goldsmith, 1952). The Bottle Spring pluton grades into the Cathedral batholith to the north. A K-Ar biotite age of 89.2 ± 0.6 Ma is reported from the Bottle Spring pluton (V. R. Todd, USGS, written commun., 1988).

Kiqm_h

Horseshoe Mountain pluton (Cretaceous)--Directionless, leucocratic, porphyritic quartz monzonite composed of tabular K-feldspar megacrysts, as much as 5 cm long, in a medium- to coarse-grained groundmass of K-feldspar, plagioclase (oligoclase), quartz, biotite, and hornblende. Some of the quartz grains form clusters as much as 1 cm across. The mafic minerals rarely exceed 5 percent of the rocks.

The Horseshoe Mountain pluton is a 35-km², north-northwest-trending intrusion in the northwestern corner of the map area. The pluton sharply cross-cuts the Tillman Mountain tonalitic gneiss. It apparently intrudes the Similkameen pluton, but the contact between the two plutons is gradational.

The Horseshoe Mountain pluton has yielded K-Ar hornblende and biotite ages of 94.6 ± 4.6 Ma and 103 ± 4 Ma, respectively (DGER unpublished data). These ages are similar to radiometric ages reported from the Cathedral batholith. They support the suggestion that the Horseshoe Mountain pluton is a porphyritic phase of the Cathedral batholith (Hibbard 1962, 1971).

Kia_a, Kid_a

Aeneas Creek pluton (Cretaceous)--A central phase of medium-grained, equigranular quartz monzonite and granodiorite (Kia_a) and a border phase of medium-grained, equigranular quartz diorite, diorite, and gabbro (Kid_a). The quartz monzonite and granodiorite are composed of plagioclase (oligoclase), K-feldspar, quartz, biotite, hornblende, and accessory sphene. Biotite and hornblende are commonly intergrown with each other and with secondary chlorite. They form approximately 15 percent of the rocks. Plagioclase, hornblende, and minor biotite and quartz are the chief components of the quartz diorite, diorite, and gabbro. These rocks are cut by and locally grade into the quartz monzonite and granodiorite, and are thought to be an early mesocratic phase of the Aeneas Creek pluton.

The quartz monzonite and granodiorite of the Aeneas Creek pluton are brecciated, silicified, and mineralized in places, particularly in the vicinity of the Starr molybdenum mine (SE1/4 sec. 8, T. 37 N., R. 26 E.) (Creasey, 1945).

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The Aeneas Creek pluton is a 5-km², northwest-trending, elongate intrusion along Aeneas Creek, 10 km west of Tonasket (T. 39 N., R. 26 E.) (Rinehart and Fox, 1976). The pluton was apparently intruded along a northwest-trending structure in the Permian Anarchist Group (Rinehart and Fox, 1976). Contacts between the pluton and the metasedimentary rocks are sharp and discordant. Swarms of pegmatite and aplite dikes and sills cut both the metasedimentary and plutonic rocks near the contacts.

Rinehart and Fox (1976) reported a K-Ar biotite age of 92.7 ± 6.6 Ma for the Aeneas Creek pluton. Concordant K-Ar hornblende and biotite ages of 92.3 ± 4.3 Ma and 98.3 ± 3.6 Ma, respectively, were obtained during this study (DGER unpublished data).

Kiqi

Lone Frank pluton (Cretaceous)--Directionless, medium- to coarse-grained quartz diorite and diorite composed of plagioclase, hornblende, biotite, quartz, and accessory magnetite, apatite, chlorite, sphene, and epidote. Mafic minerals, which commonly form small clots, comprise approximately 30 percent of the rocks. The subhedral plagioclase crystals typically consist of labradorite cores and andesine rims. The anhedral hornblende grains are commonly cored with diopsidic pyroxene.

The Lone Frank pluton is a 5-km² intrusion along Lone Frank Creek (T. 37 N., R. 23 E.) (Goldsmith, 1952; Rinehart, 1981). The pluton is massive in the interior and weakly gneissic along the borders. The contacts among the Lone Frank pluton and the Bottle Spring pluton, the Tillman Mountain tonalitic gneiss, and the metamorphic complex of Conconully are marked by narrow shear zones (Goldsmith, 1952). Contacts between the Lone Frank pluton and the Tiffany complex are gradational. The Lone Frank pluton has yielded concordant K-Ar hornblende and biotite ages of 92.7 ± 4.9 Ma and 96.9 ± 3.6 Ma, respectively (DGER unpublished data).

Kjigda

Anderson Creek pluton (Cretaceous or Jurassic?)--Granodiorite, quartz diorite, and diorite intrusions. The interior of these intrusions is composed of directionless, fine- to medium-grained, equigranular, leucocratic granodiorite; principal constituents include zoned plagioclase (oligoclase-andesine), K-feldspar (both microperthitic microcline and orthoclase), and quartz. Mafic minerals, including euhedral biotite, hornblende, chlorite, and opaque minerals, constitute less than 10 percent of the rocks. Sphene is a common accessory. The granodiorite contains scattered poikilitic K-feldspar phenocrysts in places, imparting a weak porphyritic texture to the rocks. The granodiorite is characterized by igneous textures that are locally modified by cataclasis and recrystallization.

The borders of many of the Anderson Creek intrusions consist of directionless, fine- to medium-grained quartz diorite and diorite that are compositionally similar to the granodiorite except that they contain little or no K-feldspar. These rocks were mapped as the Bowers quartz diorite and Edwards Slough diorite by Hibbard (1971), but they are herein included within the Anderson Creek pluton because they grade into the granodiorite and are probably a border phase of the intrusions (Rinehart and Fox, 1972).

The Anderson Creek pluton consists of several small intrusions on Chopaka and Grandview Mountains (T. 39 and 40 N., R. 25 E.) (Hibbard, 1962, 1971; Rinehart and Fox, 1972; Rinehart, 1981). The pluton intrudes the Kobau Formation, Loomis pluton, and Chopaka intrusive complex. Contacts are typically sharp and discordant. Hibbard (1971) reported a K-Ar biotite age of 106.5 ± 6.8 Ma for the pluton. Engels and others (1976) obtained discordant K-Ar hornblende and biotite ages of 115.6 ± 3.0 Ma and 100.1 ± 3.0 Ma, respectively. The hornblende age is probably a minimum age.

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Kjiq_b

Bowers quartz diorite (Cretaceous or Jurassic?)--Directionless, fine- to medium-grained biotite-hornblende quartz diorite along the South Fork Toats Coulee Creek (T. 39 N., R. 25 E.) (Hibbard, 1971; Rinehart and Fox, 1972; Rinehart, 1981). These small intrusions cut the Tillman Mountain tonalitic gneiss and the Late Triassic(?) Loomis pluton, and are therefore thought to be Jurassic or Cretaceous in age.

Kjigb_g

Goat gabbro (Cretaceous or Jurassic?)--Black, directionless, medium- to coarse-grained gabbro. It cuts the Chopaka intrusive complex and grades into the dioritic border phase of the Anderson Creek pluton (Hibbard, 1971; Rinehart, 1981). The gabbro of this 1-km² intrusion on Chopaka Mountain (sec. 24, T. 40 N., R. 24 E.) is compositionally and texturally similar to the diorite in the Anderson Creek pluton, which suggests that the two intrusions may be comagmatic (Hibbard, 1971). A Cretaceous or Jurassic age is therefore tentatively assigned.

Kjia_w, Kjii_w

Whisky Mountain pluton (Cretaceous or Jurassic?)--A central phase of medium- to coarse-grained, porphyritic granodiorite and quartz monzonite (Kjia_w) and a border phase of fine-grained, equigranular mesocratic monzonite and quartz diorite (Kjii_w).

The porphyritic granodiorite and quartz monzonite are composed of euhedral microperthitic microcline crystals, as much as 5 cm across, in a medium- to coarse-grained groundmass of plagioclase (oligoclase-albite), microcline, and quartz. Some of the anhedral quartz crystals are clustered together, forming small glomerocrysts. Biotite, chlorite, epidote, and magnetite are the chief mafic minerals. They are commonly intergrown, forming masses that are apparently pseudomorphous after hornblende. A few relict hornblende crystals are also present. Sphene and epidote are common accessory minerals. The mesocratic monzonite and quartz diorite are compositionally similar to the porphyritic rocks, except that they contain less microcline and quartz and more hornblende and biotite. The equigranular, mesocratic rocks are cut by the porphyritic rocks in places, indicating that the border phase is older.

The Whisky Mountain pluton is a 15-km², northwest-trending, elongate intrusion between Wannacut Lake and the Okanogan River valley north of Ellisforde (T. 38 and 39 N., R. 27 E.) (Krauskopf 1938; Waters and Krauskopf, 1941; Fox, 1970; Rinehart and Fox, 1972). Igneous textures dominate the pluton. Most of the rocks are directionless, but a weak foliation is locally developed along the borders of the intrusion. The southeastern part of the pluton, east of the Okanogan River, has been cataastically deformed along the Okanogan fault.

The Whisky Mountain pluton intrudes the Permian Anarchist Group. Hornblende from mesocratic quartz diorite near the center of the pluton yielded a K-Ar age of 119 ± 5 Ma (DGER unpublished data). However, because much of the pluton has been strongly altered, it is unlikely that this radiometric age represents the magmatic crystallization age.

Kjii_s

Silver Nail Lake pluton (Cretaceous or Jurassic?)--Concentrically-zoned intrusion of quartz diorite and diorite. The central phase is medium-grained quartz diorite and granodiorite(?), and the border phase is fine-grained diorite (E. S. Cheney, University of Washington, written commun., 1990). Feldspar, quartz,

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hornblende, biotite, and epidote(?) were the original mineral constituents of the quartz diorite, but most of the feldspar has been altered to epidote, calcite, and sericite and the mafic minerals have been replaced by chlorite. Apatite, magnetite, and sphene are common accessory minerals. The composition of the diorite is similar to that of the quartz diorite, but the diorite contains little or no quartz. The pluton is not foliated, but it is cut by shear zones containing veins of epidote, quartz, calcite, and sulphide minerals.

The 3-km² Silver Nail Lake pluton crops out along the west side of Osoyoos Lake (T. 39 N., R. 27 E.) in the United States and extends north into British Columbia (Daly, 1912; Krauskopf, 1938; Fox, 1970). All that is known about its age is that it cuts the Kobau Formation. Because it is not foliated, a Cretaceous or Jurassic age is probable.

Kjigd_d

Dunn Mountain pluton (Cretaceous or Jurassic?)--Composition highly varied. Massive to weakly foliated, fine- to medium-grained granodiorite is the dominant lithology; syenodiorite, diorite, and quartz diorite are subordinate. Biotite and hornblende, in approximately equal proportions, make up approximately 15 percent of the rocks.

The Dunn Mountain pluton consists of four small intrusions that occupy an area of approximately 5 km² near the town of Conconully (Rinehart and Fox, 1976; Rinehart, 1981). It intrudes the metamorphic complex of Conconully and granodioritic gneiss of Salmon Creek. Contacts between the pluton and the country rocks are typically sharp and discordant, but concordant contacts are observed in places. Fine-grained chilled margins and intrusion breccias are present locally. The age of the Dunn Mountain pluton is uncertain. Its cross-cutting relation with the granodioritic gneiss of Salmon Creek suggests it is post-Triassic. A Cretaceous or Jurassic age is suspected.

Kjigd_b, Kjid_b

Buckhorn Mountain pluton (Cretaceous or Jurassic?)--A central phase of gray, fine- to medium-grained, biotite-hornblende granodiorite with minor alaskite and quartz porphyry (Kjigd_b) and a border phase of dark-gray, fine-grained hornblende diorite (Kjid_b). Scattered dikes of pale-green to gray, fine-grained hornblende diorite cut the granodiorite.

Much of the Buckhorn Mountain pluton is hydrothermally altered. Secondary minerals include saussurite, epidote, biotite, sericite, and chlorite. The pluton is locally cut by sericitic shear zones that vary from a few meters to tens of meters wide.

The Buckhorn Mountain pluton occupies approximately 20 km² in the northeastern corner of the Oroville 1:100,000-scale quadrangle, the northwestern corner of the Republic 1:100,000-scale quadrangle, and southern British Columbia (Daly, 1912; Pearson, 1967; Fox, 1978; McMillen, 1979; Tempelman-Kluit, 1989). It cuts Kobau Formation(?) metavolcanic rocks and Anarchist Group metasedimentary rocks. Contact metamorphism by the pluton has locally transformed the metasedimentary rocks into hornfels, marble, and garnet-epidote-magnetite skarn.

The age of the Buckhorn Mountain pluton is poorly constrained. It must be post-middle Permian because it cuts the Anarchist Group. Compositionally similar intrusions in southern British Columbia have yielded middle Jurassic to Cretaceous ages (Little, 1957; Tempelman-Kluit, 1989).

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Kjigd_w

Wauconda pluton (Cretaceous or Jurassic?)--Gray, medium- to coarse-grained, porphyritic granodiorite and quartz monzodiorite composed of blocky K-feldspar megacrysts, as much as 7 cm across, in a medium- to coarse-grained groundmass of plagioclase (oligoclase-andesine), quartz, and K-feldspar. Hornblende and biotite typically form 5 to 10 percent of the rocks. Accessory minerals include sphene, apatite, allanite, epidote, zircon, monazite(?), and opaque minerals.

The Wauconda pluton is directionless to weakly foliated. The foliation is best developed near the contact with the Mount Bonaparte pluton. Thin-sections reveal that the gneissic rocks have suffered cataclasis and recrystallization. Evidence includes

"1) xenomorphic-granular texture, 2) rounded K-feldspar phenocrysts with milled-off corners; 3) intergranular mortar (recrystallized); 4) locally entrained apatite; 5) bent, broken, and rehealed plagioclase showing distorted or offset twin lamellae; 6) undulose, flamboyantly recrystallized quartz, commonly showing implication texture" (Rinehart and Greene, 1988, p. 6).

This northwest-trending intrusion lies along the eastern border of the Oroville 1:100,000-scale quadrangle and the western border of the Republic 1:100,000-scale quadrangle (Fox, 1978; Rinehart and Greene, 1988; C. D. Rinehart, USGS, written commun., 1988).

The age of the Wauconda pluton is poorly constrained. It intrudes schist (pTsc) and marble (pTmb) of unknown age and is cut by the early Tertiary Mount Bonaparte pluton. A Jurassic or Cretaceous age is suspected.

Jiqm_s

South Fork quartz monzonite (Jurassic?)--Massive to weakly foliated, medium- to coarse-grained quartz monzonite. Principal constituents are plagioclase (oligoclase), K-feldspar, quartz, biotite, and hornblende. The color index is approximately 10.

The unit forms a 12-km², northeast-trending elongate intrusion along the South Fork Toats Coulee Creek (Hibbard, 1962, 1971; Rinehart, 1981). The quartz monzonite intrudes the Tillman Mountain tonalitic gneiss, the North Fork Camp hybrid gneiss, and the heterogeneous metamorphic rocks near Toats Coulee Creek. Contacts with the Tillman Mountain tonalitic gneiss and the North Fork Camp hybrid gneiss are gradational. Contacts with the heterogeneous metamorphic rocks are generally sharp.

Discordant K-Ar hornblende and biotite ages of 162 ± 7.0 Ma and 131 ± 5.0 Ma, respectively, have been obtained from the South Fork quartz monzonite (DGER unpublished data).

Jia_s, Jik_s

Similkameen pluton (Jurassic)--The Similkameen pluton is a 350-km², east-trending, oval intrusion that straddles the Canadian border along the Similkameen River (T. 40 N., R. 23 to 26 E.) (Daly, 1912; Campbell, 1939; Bostock, 1940; Lounsbury, 1951; Hibbard, 1962, 1971; Rinehart and Fox, 1972; Fox, 1973; Rinehart, 1981). The pluton is a concentrically zoned intrusion, composed of a central phase of quartz monzonite, granodiorite, and monzonite (Jia_s), and a discontinuous border phase of mesocratic shonkinite, nepheline syenite, pyroxenite, and minor malignite (Jik_s). Dikes and irregular bodies of alaskite cut both the central and border phases in places, but cut only the border phase in other places. Cross-cutting relation suggest that the order of intrusion was: (1) pyroxenite; (2) malignite-shonkinite; (3) nepheline syenite; (4) monzonite-granodiorite-quartz monzonite; and (5) alaskite.

The Similkameen pluton intrudes the Chopaka intrusive complex, the Kobau Formation, and the heterogeneous metamorphic rocks near Toats Coulee Creek (pJhm). Contacts with the country rocks are generally sharp and discordant.

Several strongly discordant K-Ar ages and a Rb-Sr isochron age of 170 ± 5 Ma are reported from the Similkameen pluton in the map area (Table 1). A concordant U-Pb zircon age of 170 ± 2 Ma is reported from granodiorite along the northern border of the pluton near Keremeos, British Columbia (Parkinson, 1985).

Jia_s

Granodiorite and quartz monzonite--Massive granodiorite, quartz monzonite, and monzonite, typically medium to coarse grained and porphyritic, but non-porphyritic varieties also are present, particularly near the center of the pluton. The porphyritic rocks are composed of scattered tabular phenocrysts of microperthitic microcline, as much as 2 cm long, in a medium-grained groundmass of plagioclase, K-feldspar, quartz, hornblende, biotite, and epidote. Hornblende crystals commonly contain pyroxene cores. Spheine and zircon are common accessory minerals. With the exception of the lack of microcline phenocrysts, the non-porphyritic rocks are petrographically similar to the porphyritic rocks. The central phase forms more than 90 percent of the Similkameen pluton. A progressive decrease in quartz content toward the margins of the central phase has resulted in a crude zonation from quartz monzonite to granodiorite to monzonite. The monzonite grades into malignite-shonkinitic along the borders of the pluton.

Dikes and irregular masses of alaskite, too small to show on the 1:100,000-scale map, cut both the central phase granitic rocks and the border phase alkalic rocks. The alaskite bodies sharply crosscut the other rocks, indicating they were intruded after solidification of the main mass of the pluton. The fine- to medium-grained alaskite consists of oligoclase, microcline, quartz, and accessory muscovite, biotite, sphene, magnetite, zircon, apatite, and garnet.

Jik_s

Alkalic rocks--Melanocratic alkalic rocks forming a narrow, concave belt on the southeastern border of the Similkameen pluton (Fox, 1973; A. M. Buddington, Western Washington University, written commun., 1987); malignite, shonkinitic, nepheline syenite, and pyroxenite are the dominant lithologies.

The malignite and shonkinitic are directionless to strongly gneissic, fine- to medium-grained rocks, composed of perthitic microcline, andesine (with albite rims), augite, hastingsite, biotite, nepheline, hydromica (after nepheline), garnet, and a variety of zeolite minerals. The directionless rocks are locally porphyritic, with microcline phenocrysts as much as 6 cm long. Parallel alignment of the phenocrysts imparts a trachytoid texture to the porphyritic rocks in places. Oriented biotite and microcline crystals define the foliation in the weakly gneissic rocks, while the strongly gneissic rocks are characterized by the segregation of felsic and mafic minerals into subparallel bands a few millimeters to a few centimeters thick.

The medium- to coarse-grained syenite consists of sodic oligoclase, microcline, and minor garnet, biotite, epidote, calcite, and nepheline (or its alteration products, cancrinite and analcite). Minor hastingsite and augite are present in some, but not all of the syenite. Accessory minerals include muscovite, apatite, sphene, and magnetite. The syenite is weakly to moderately foliated in most places. The foliation strikes parallel to the contact between the syenite and the country rocks, and it typically dips 65° to 90° to the southeast.

Augite is the chief constituent of the massive, fine- to coarse-grained pyroxenite. Hastingsite, apatite, magnetite, and sphene are minor components. Some of the pyroxenite bodies contain as much as 50 percent biotite, but other bodies are biotite-free.

Jik_b

Shankers Bend alkalic complex (Jurassic?)--Brecciated mesocratic alkalic gneiss, malignite, shonkinite, and monzonite. The core of the complex is composed of mesocratic alkalic gneiss of foyaitic to shonkinitic composition. On the south side of the complex, the alkalic gneiss grades into fenitized (alkali metasomatized) metasiltstone of the Ellemeham Formation. Along the west side of the complex, the alkalic gneiss grades into shattered and brecciated greenstone, metasiltstone, and metachert of the Kobau and Ellemeham Formations. On the eastern margin of the complex, the alkalic gneiss grades into two small bodies of malignite and shonkinite. Brecciated monzonite forms a small tabular mass on the southeastern flank of the complex.

The mesocratic alkalic gneiss in the Shankers Bend alkalic complex is fine to medium grained and weakly foliated to indistinctly layered. It consists of 50 to 75 percent perthitic K-feldspar, plagioclase, and hydromica (pseudomorphous after nepheline), and 25 to 50 percent mafic minerals, including aegirine-augite, hastingsite, and biotite. Accessory minerals include garnet, apatite, sphene, cancrinite, calcite, clinozoisite, magnetite, and various zeolites. Foliation in the gneiss is typically penetrative, curving, and anastamosing. Most of the alkalic gneiss is weakly to strongly brecciated. The strongly brecciated rocks consist of angular to subrounded pebble-size clasts of gneiss in a matrix of finely comminuted gneiss fragments and crystals of its component minerals.

The malignite in the Shankers Bend alkalic complex is composed of perthitic K-feldspar, andesine, hastingsite, augite, nepheline or hydromica, and accessory magnetite, biotite, apatite, and sphene. It grades into shonkinite that is composed of the same mineral constituents but lacks nepheline or hydromica. The malignite and shonkinite are chiefly directionless, medium-grained, equigranular rocks, but they are locally gneissose. Both are broken to brecciated in places. The brecciated monzonite consists of pebble- to cobble-size clasts of monzonite in a matrix of finely comminuted rock fragments and crystals. Composition and texture of the monzonite clasts are highly varied. Grain size ranges from fine to coarse; both equigranular and porphyritic varieties are present. The color index of the monzonite clasts varies from 5 to 35.

Carbonate, feldspar, monzonite, and aplite dikes cut the malignite, shonkinite, and alkalic gneiss in the Shankers Bend alkalic complex. They are generally thin (<2 m wide) and short (<15 m long). The carbonate dikes consist of medium- to coarse-grained calcite and accessory muscovite, apatite, diopside, feldspar, and graphite. The feldspar dikes are composed of coarse-grained perthitic microcline and oligoclase. The monzonite and aplite dikes consist of K-feldspar and plagioclase, with or without quartz.

The shonkinite, monzonite, and malignite in the Shankers Bend alkalic complex crystallized directly from magma (Fox, 1973). The alkalic gneiss formed by fenitization (alkali metasomatism) of greenstone, metasiltstone, and metachert of the Kobau and Ellemeham Formations. Brecciation of the rocks within and adjacent to the complex probably occurred before, during, and after intrusion of the magma and fenitization of the country rocks.

The Shankers Bend alkalic complex occupies 1 km² and crops out in the hills 2 km south of Shankers Bend on the Similkameen River (T. 40 N., R. 26 E.) (Rinehart and Fox, 1972; Fox, 1973). The complex intrudes the Jurassic(?) Ellemeham Formation and is unconformably overlain by Eocene conglomerate. The striking similarity in composition and character between the Shankers Bend alkalic complex and the alkalic border phase of the Similkameen pluton "suggest that they were probably

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emplaced during the same episode of plutonism and are derived from the same magmatic source" (Rinehart and Fox, 1972, p. 59). Therefore, a Middle Jurassic age is suspected.

JTRigd_b

Blue Goat pluton (Jurassic or Triassic?)--A zoned pluton that consists of a central phase of directionless, subporphyritic granodiorite composed of scattered subhedral microcline phenocrysts, as much as 2 cm long, in a medium-grained groundmass of plagioclase (oligoclase-andesine), quartz, and hornblende. Biotite, epidote, and sphene are common accessory minerals. Mafic minerals typically compose 20 percent of the rocks. The directionless granodiorite grades outward into a border phase of weakly to moderately gneissic granodiorite that contains more mafic minerals than the directionless rocks. Igneous textures dominate the directionless granodiorite in the interior of the pluton, but crystalloblastic textures are characteristic of the border phase gneissic rocks. Thin aplite and fine-grained granodiorite and quartz monzonite dikes cut the pluton in places.

The Blue Goat pluton is a 40-km², north-south-trending intrusion between Fish and Blue Lakes (T. 36 and 37 N., R. 25 E.) (Rinehart and Fox, 1976; Rinehart, 1981). It cuts the Anarchist Group and the metamorphic complex of Conconully. The pluton is roughly concordant with the regional foliation in the metamorphic rocks, but contacts are locally sharp and discordant. Inclusions of metamorphic rocks are common in the pluton. Granodiorite dikes and sills emanating from the pluton cut the country rocks in places.

"The local discordance, yet general concordance, of the pluton suggests that the country rocks had been deformed and metamorphosed prior to emplacement of the pluton and probably exerted considerable influence on its final shape" (Rinehart and Fox, 1976, p. 32).

Discordant K-Ar hornblende and biotite ages of 141.8 ± 8.2 Ma and 99.3 ± 3.0 Ma, repectively, are reported from this pluton (Rinehart and Fox, 1976).

JTRigd_l

Loomis pluton (Jurassic or Triassic?)--Massive to weakly foliated, medium-grained, equigranular granodiorite and tonalite. Principal constituents of the rocks are quartz, plagioclase (oligoclase-andesine), microperthitic microcline, and euhedral hornblende and biotite. The color index ranges from 5 to 15. Quartz grains commonly occur in aggregates or clots, a characteristic that readily distinguishes the Loomis pluton from surrounding intrusions. Aplite dikes and irregular masses of aplite and pegmatite cut the granodiorite and tonalite in places.

The granodiorite and tonalite in the southern half of the Loomis pluton are weakly porphyritic and contain more mafic minerals than the rocks in the northern half. They are composed of scattered anhedral microcline phenocrysts, 5 to 15 mm long, in a medium-grained groundmass similar in composition to the equigranular rocks in the northern part of the pluton. The small isolated intrusion on the north side of Sinlahekin Creek (secs. 17 and 18, T. 37 N., R. 25 E.) is compositionally similar to, but more strongly foliated than the Loomis pluton to the north. Rinehart and Fox (1972, 1976) thought the intrusion is a satellite of the Loomis pluton, but Hibbard (1971) believed it represents a separate pluton.

The Loomis pluton is a 180-km², north-northwest-trending, elongate intrusion between Chopaka Mountain (T. 40 N., R. 24 E.) and Blue Lake (T. 37 N., R. 25 E.) (Goldsmith, 1952; Hibbard, 1962, 1971; Rinehart and Fox, 1972, 1976; Rinehart, 1981). The pluton intrudes the Kobau Formation, the

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Anarchist Group, and the Chopaka intrusive complex. Contacts are typically sharp and discordant, but the border of the pluton is locally brecciated. Dikes and sills emanating from the pluton invade the country rocks in places, and inclusions of country rocks are common in the border of the pluton.

Discordant K-Ar hornblende and biotite ages of 194 ± 6 Ma and 179 ± 5 Ma, respectively, are reported (Rinehart and Fox, 1972).

Tr_{ib_m}

Metagabbro and amphibolite near Mud Lake (Triassic?)--Massive rocks composed of abundant equant, 1-cm-long hornblende crystals in a granoblastic matrix of plagioclase and actinolite. They form three small intrusions that crop out northeast of Mud Lake (T. 36 N., R. 26 E.) (Rinehart and Fox, 1976). The metagabbro and amphibolite cuts phyllite and metasiltstone in the metamorphic complex of Conconully whose age is thought to be Late Triassic (at least in part). Thin beds of amphibolite are interlayered with the phyllite and metasiltstone near the intrusions. The amphibolitic interlayers are concordant with bedding in the metasedimentary rocks, and are weakly foliated parallel to the foliation in the phyllite and metasiltstone. The close association of the metagabbro and amphibolite with amphibolite-rich metasedimentary rocks in the complex

"suggest that the large mapped masses and the adjacent amphibolite-rich terrane are vestiges of a paleovolcanic center that is partly contemporaneous with the surrounding rocks and partly later, but is unquestionably older than the regional metamorphism" (Rinehart and Fox, 1976, p. 19).

Therefore, a Late Triassic age is suspected.

Mesozoic or Paleozoic Intrusive Igneous Rocks

$\text{Tr}_{\text{Rnib}_c}, \text{Tr}_{\text{Rnu}_c}$

Chopaka intrusive complex (Triassic or Permian?)--Metamorphosed gabbro, dunite, peridotite, pyroxenite, and minor clinopyroxenite and norite. Most of the rocks are recrystallized, but igneous textures are locally preserved. Layering and foliation in the complex are concordant with foliation in the surrounding country rocks, indicating that recrystallization occurred during regional metamorphism.

The Chopaka intrusive complex on Chopaka Mountain (T. 40 N., R. 24 and 25 E.) (Hibbard, 1962, 1971; Rinehart and Fox, 1972) intrudes the Kobau Formation and is cut by the Late Triassic(?) Loomis pluton and the Middle Jurassic Similkameen pluton. Metagabbro in the complex has yielded a K-Ar actinolitic hornblende age of 190.5 ± 15.6 Ma, which suggests that metamorphism occurred in the Early Jurassic. E. S. Cheney (University of Washington, written commun., 1990) believes that the Chopaka intrusive complex and the Palmer Mountain Greenstone represent an ophiolite complex that lies along a regional thrust fault.

$\text{Tr}_{\text{Rnib}_c}$

Metagabbro--Fine- to coarse-grained metagabbro composed of recrystallized calcic plagioclase, actinolitic hornblende, and minor diopsidic pyroxene. The metagabbro is weakly to strongly foliated and commonly distinctly layered. The layers, which are complexly folded and swirled in places, are defined by contrasting grain sizes that are a reflection of the degree of recrystallization of the rocks.

The metagabbro is locally cut by anastamosing veinlets of epidote, grossularite-andradite, zoisite, sodic plagioclase, calcite, and muscovite. The veins apparently formed by saussuritization of the metagabbro during intrusion of younger granitoid rocks.

The presence of minor calcic plagioclase-bearing clinopyroxenite, olivine-bearing gabbro, and norite in the Chopaka intrusive complex indicates that a compositional gradation exists between the metagabbro and the ultrabasic rocks, and suggests that all of the rocks formed during the same intrusive event (Hibbard, 1962, 1971).

T_R RmU_c

Ultrabasic rocks--Massive dunite, peridotite, and pyroxenite. Primary minerals are forsterite, enstatite, diopside, magnetite, and chromite, but alteration of the rocks is commonly so advanced that few primary minerals remain. Secondary minerals include anthophyllite, actinolite, tremolite, antigorite, and talc. Thin (<1 cm thick) veins of chrysotile asbestos cut the ultrabasic rocks in places.

T_R RmB

Basic intrusive rocks (Triassic or Permian?)--Metadiabase, metagabbro metadiorite, and greenstone composed of plagioclase (albite-andesine), actinolitic hornblende, epidote/clinozoisite, quartz, chlorite, calcite, sericite, and opaque minerals. Common accessory minerals include apatite, sphene, K-feldspar, and biotite. Some of the hornblende grains are cored with pyroxene, and others are pseudomorphous after pyroxene. Geochemical analyses of the rocks suggest that most were originally andesitic in composition, but some were probably as basic as basalt. Composition of the basic intrusive rocks is similar to that of igneous rocks in the Chopaka intrusive complex, the Palmer Mountain Greenstone, and the Kobau Formation (Hibbard, 1971; Rinehart and Fox, 1972), which suggests that all were derived from a common magma. Stratigraphic and cross-cutting relations indicate all are of roughly coeval. Therefore, the basic intrusive rocks are thought to be of Late Permian or Triassic age.

These basic intrusive rocks cut the Anarchist Group and Kobau Formation (Fox, 1970, 1978; Rinehart and Fox, 1972, 1976). Some of the bodies are discordant with layering in the enclosing metasedimentary and metavolcanic rocks, but most are grossly concordant. However, satellite dikes emanating from many of the concordant bodies demonstrate that they are intrusive.

Metamorphic Rocks

Metamorphic Rocks in the Okanogan metamorphic core complex

The Okanogan metamorphic core complex is a 90-km-long by 45-km-wide belt of upper amphibolite facies metamorphic rocks and orthogneisses that forms most of the eastern half of the Oroville 1:100,000-scale quadrangle and extends south and east into the Omak, Nespelem, and Republic 1:100,000-scale quadrangles. It is the westernmost of four metamorphic core complexes in the Okanogan highlands of northeastern Washington that occupy the southern end of the Omineca crystalline belt (Figs. 5 and 6).

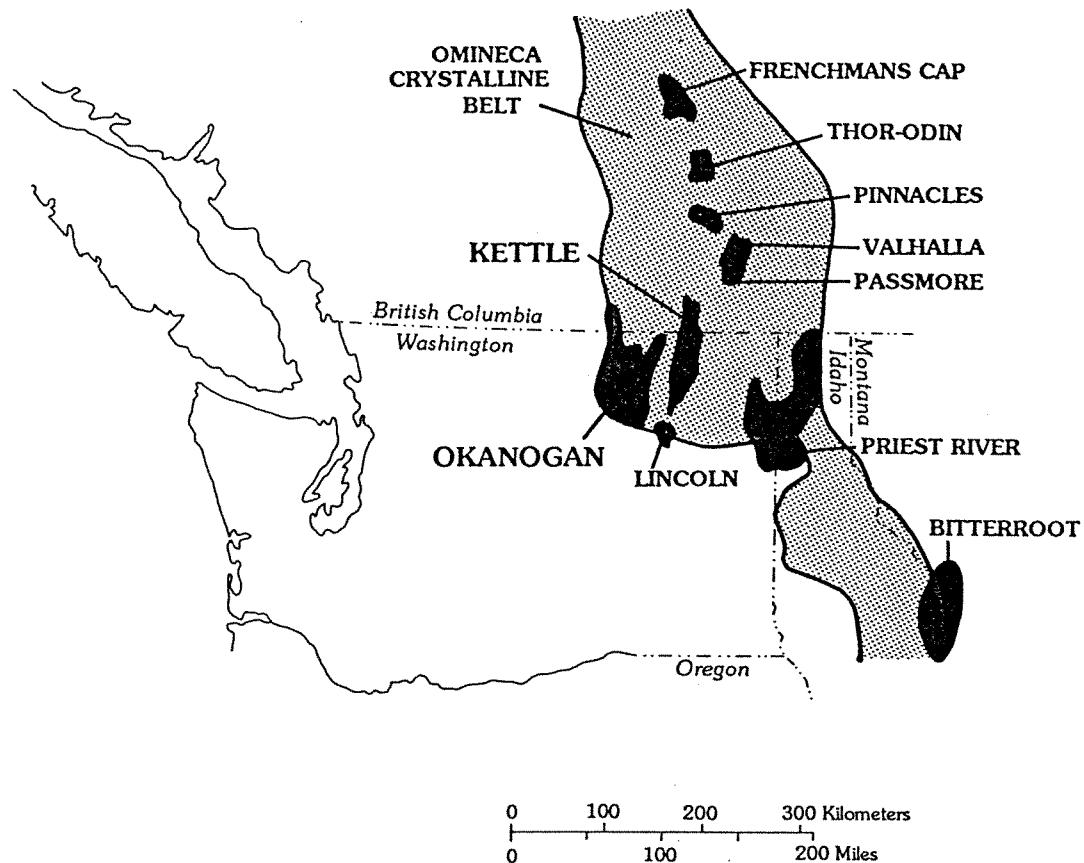


Figure 5. Metamorphic core complexes in the Omineca crystalline belt of northeastern Washington and adjacent areas (after Orr and Cheney, 1987).

The Okanogan metamorphic core complex is a heterogeneous assemblage of banded gneiss, schist, and amphibolite, leucocratic granitoid orthogneiss, and directionless granodioritic to monzodioritic plutons (Snook, 1962, 1965; Fox and others, 1976, 1977; Cheney and others, 1982; Orr and Cheney, 1987; Hansen and Goode, 1988). All metamorphic rocks in the Okanogan complex were assigned to the Tonasket Gneiss by Snook (1962, 1965), but Fox and others (1976) redefined the Tonasket Gneiss to include only the layered metamorphic rocks. The granitoid orthogneisses and plutonic rocks that were excluded from the Tonasket Gneiss were subsequently assigned a variety of informal names.

The rocks in the Okanogan metamorphic core complex have been cataastically deformed and recrystallized to various degrees (Krauskopf, 1938; Waters and Krauskopf, 1941; Snook, 1965; Fox and

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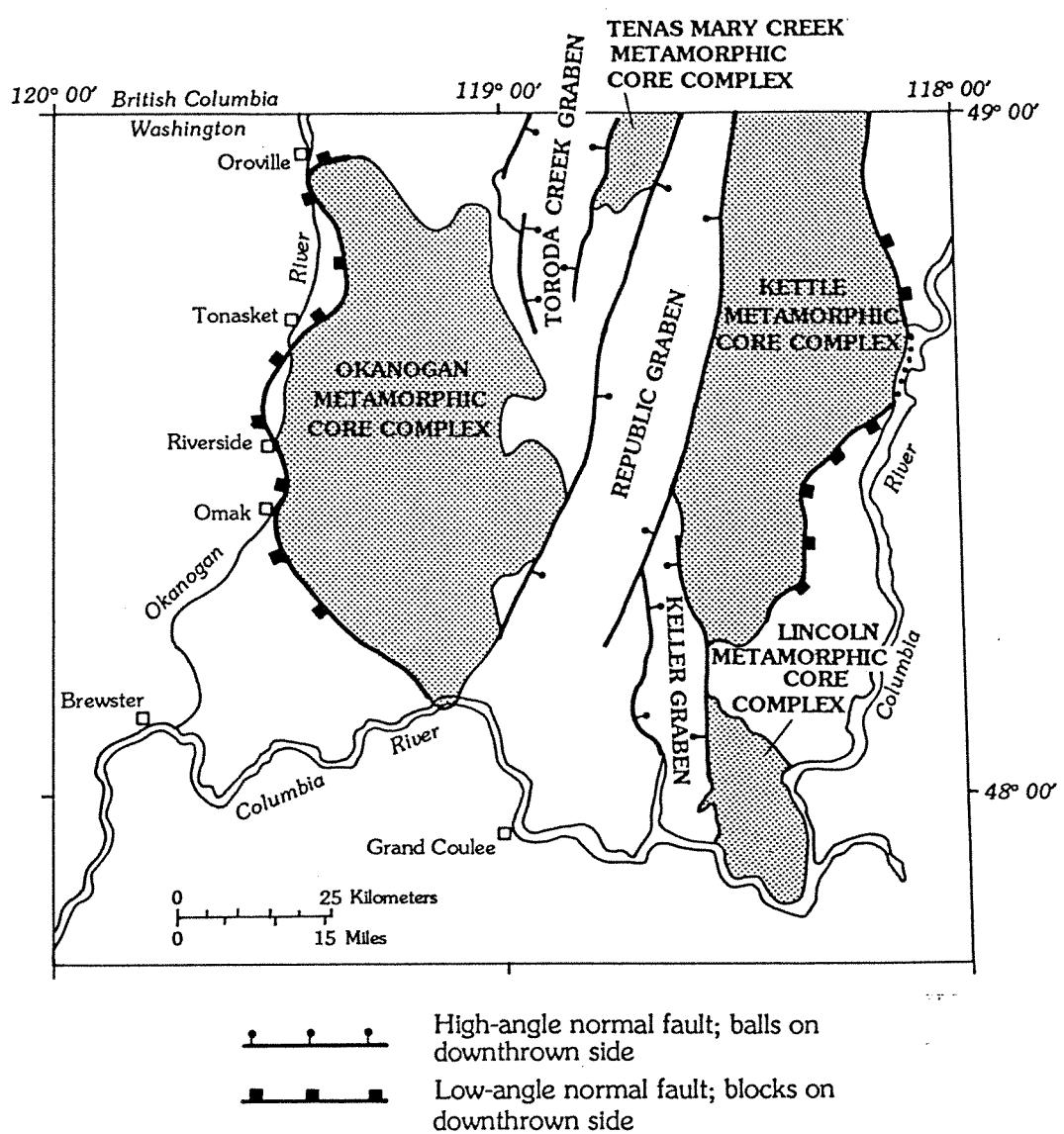


Figure 6. Metamorphic core complexes in the Okanogan highlands of northeastern Washington (after Fox and Rinehart, 1988).

Rinehart, 1988). Ultramylonitic¹, mylonitic, and protomylonitic rocks form a belt less than 5 km wide along the western and southern margin of the complex. They grade inward into blastomylonitic rocks, which in turn grade into recrystallized, but non-mylonitic gneiss in the interior of the complex.

The metamorphic rocks in the Okanogan core complex are foliated, lineated, folded, and faulted. In general, the dip of the foliation is subhorizontal in the interior of the complex and steeper along the margins of the complex (Fox and Rinehart, 1988). In detail, the attitudes of foliation and layering in the Okanogan metamorphic core complex define three broad, northwest-trending antiforms separated by two narrow, northwest-trending synforms (Fig. 7). Lineations in the recrystallized metamorphic rocks in the interior and eastern parts of the complex are defined by aligned hornblende crystals; they generally trend N60°W. Lineations in the penetratively deformed mylonitic rocks are defined by crushed and smeared-out mineral fragments; they generally trend N60°E. Isoclinal recumbent folds, characterized by large amplitude/wavelength ratios, are common in both the recrystallized and mylonitically deformed rocks. Axes of the folds typically trend northwest and plunge shallowly northwest or southeast. Broad, open folds with northwest-trending axes are also common in the mylonitic rocks. North-northeast-trending, steeply dipping faults and fractures cut the mylonitic rocks, particularly along the west side of the core complex.

The Okanogan metamorphic core complex is bordered on the west by the Okanogan fault, a low-angle normal fault that separates the amphibolite-facies metamorphic rocks in the complex from Paleozoic and Mesozoic greenschist-facies metasedimentary and metavolcanic rocks, Mesozoic intrusive igneous rocks, and Eocene volcanic and sedimentary rocks. The northeastern border of the core complex in the map area is marked by a narrow, discontinuous belt of monzonitic and syenitic gneiss (pTgn) (Krauskopf, 1938; Waters and Krauskopf, 1941; Fox and others, 1976).

K-Ar and fission-track ages from the Tonasket Gneiss and the orthogneisses in the Okanogan metamorphic core complex range from 66 Ma to 46 Ma (Fox and others, 1976) (Table 1). These ages suggest that uplift and cooling of the complex began approximately 65 Ma, and that the core complex "cooled slowly through the successive temperature thresholds for sphene, epidote-allanite, hornblende, and finally apatite-muscovite-biotite..." (Fox and others, 1976, p. 1223). Thus, all the metamorphic rocks in the Okanogan core complex are pre-Tertiary in age. Three U-Pb zircon ages between 87 and 100 Ma are reported for the Tonasket Gneiss (Fox and others, 1976) (Table 1). A U-Pb zircon age of 201.5 ± 2.2 Ma is reported for the orthogneiss of Osoyoos (Parkinson, 1985).

Meta-igneous Rocks

pTog_m

Gneissic porphyritic granodiorite of Mission Creek (pre-Tertiary?)--Gray, fine- to medium-grained, equigranular, granodioritic gneiss composed of plagioclase, quartz, and minor K-feldspar, biotite, and hornblende that grades to the southeast into porphyritic granodioritic gneiss composed of sparse (<5 percent) K-feldspar megacrysts (2-8 cm in diameter) in an equigranular, medium-grained groundmass of plagioclase, quartz, biotite, and minor sphene and iron oxide. The color index is typically between 5 and 10.

¹Cataclastic rock definitions after Higgins (1971):

Ultramylonite--A rock composed of sparse porphyroclasts, typically less than 2 mm in diameter, scattered throughout an aphanitic matrix of finely crushed minerals.

Mylonite--A rock composed of 10 to 50 percent porphyroclasts, typically greater than 2 mm in diameter, in an aphanitic matrix of finely crushed minerals.

Protomylonite--A rock composed of lenticular lithic masses separated by thin films of finely crushed minerals.

Blastomylonite--A rock with a megascopic fabric similar to any of the above, but with a granoblastic matrix of recrystallized minerals instead of finely crushed minerals.

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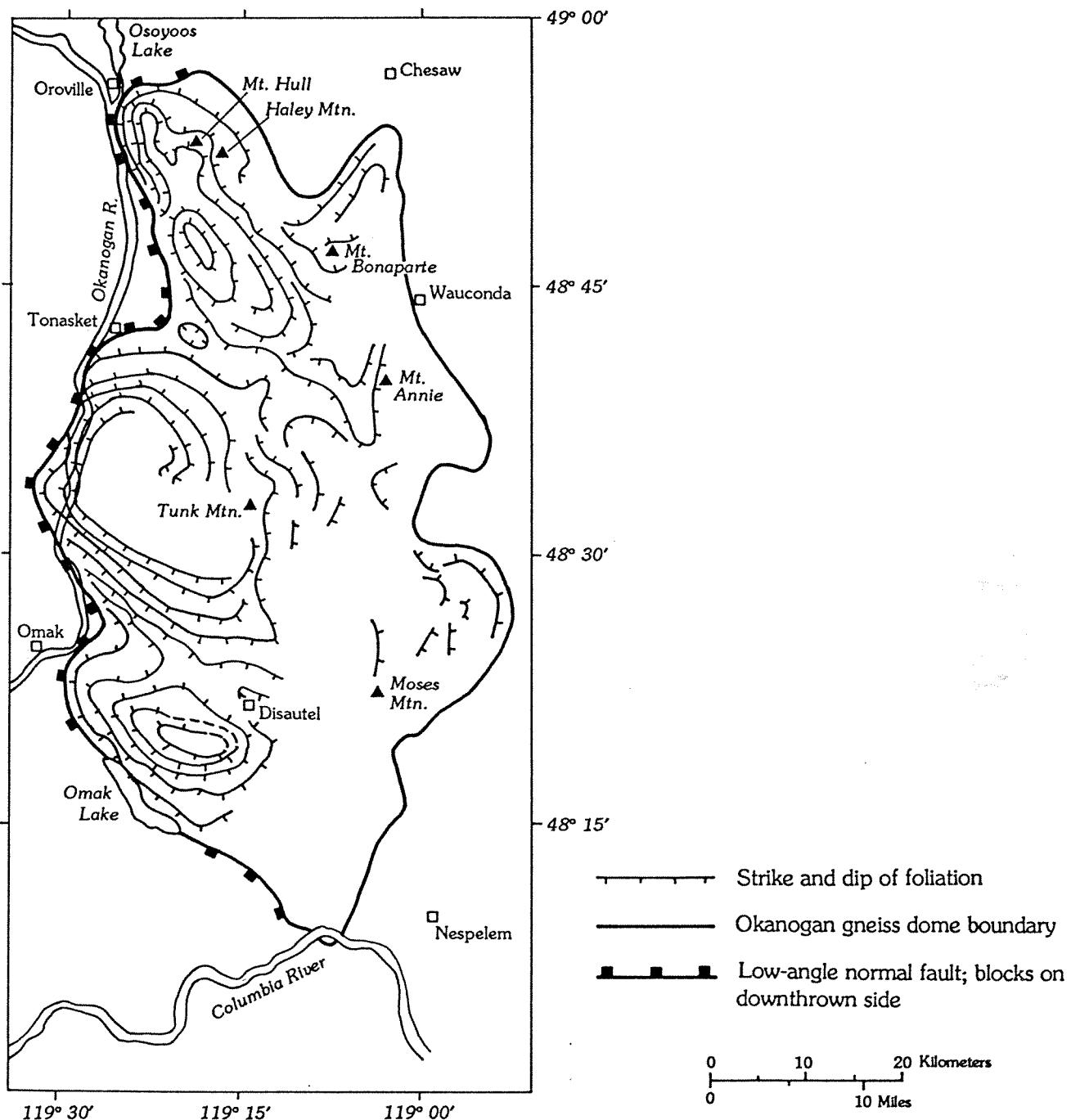


Figure 7. Geologic structures in the Okanogan gneiss dome (after Fox and Rinehart, 1988).

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Most of the gneissic porphyritic granodiorite of Mission Creek has been cataastically deformed and recrystallized into strongly foliated and lineated, porphyroclastic mylonite gneiss. Along the west side of the Okanogan core complex, the intrusion is distinctly layered. It consists of bands of light-gray felsic rocks, gray microporphyroclastic rocks, and black ultramylonitic rocks. The layers are commonly folded into tightly appressed, recumbent S-folds (Fox and Rinehart, 1988).

The unit is a broad, northwest-trending intrusion along the southwestern border of the Okanogan complex between Wagonroad Coulee (in the Oroville 1:100,000-scale quadrangle) and Omak Lake (in the Omak 1:100,000-scale quadrangle) (Goodge and Hansen, 1983; Atwater and Rinehart, 1984; Rinehart and Fox, 1976; Fox and Rinehart, 1988; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). It cuts the Tonasket Gneiss and locally contains abundant inclusions of it. A K-Ar biotite age of 47.2 ± 1.4 Ma is reported from the gneissic porphyritic granodiorite of Mission Creek in the Omak 1:100,000-scale quadrangle (Atwater and Rinehart, 1984). It is probably a metamorphic age. Crystallization age of the intrusion is unknown.

pTog_c

Crawfish Lake tonalite gneiss (pre-Tertiary?)--Gray porphyroclastic granodiorite gneiss composed of sparse K-feldspar porphyroclasts, as much as 3 cm across, in a medium-grained, equigranular groundmass of plagioclase, quartz, biotite, and minor hornblende. Some of the hornblende contains relict cores of pyroxene. Accessory minerals include zircon, sphene, allanite, and epidote. The average color index is 10.

The Crawfish Lake tonalite gneiss is weakly to strongly foliated and lineated and is mylonitic in places. Orthoclase augen and recrystallized biotite and quartz grains are characteristic of the penetratively deformed rocks.

The Crawfish Lake tonalite gneiss is a narrow, north-trending intrusion that straddles the border between the Oroville and Omak 1:100,000-scale quadrangles near Aeneas Mountain (T. 35 N., R. 29 E.) (Singer, 1984; Gulick, 1987). Little is known about its age except that it intrudes the Tonasket Gneiss and is cut by the Swimpkin Creek pluton (49 Ma). This tonalite gneiss may be correlative with the gneissic granodiorite of French Valley in the Omak 1:100,000-scale quadrangle (Atwater and Rinehart, 1984).

pTog_a

Orthogneiss of Anglin (pre-Tertiary?)-- Principally plagioclase, quartz, K-feldspar, biotite, and hornblende. K-feldspar content is highest (as much as 40 percent) in the center of the intrusion. Mafic mineral content of the gneiss increases to the west.

Though generally homogeneous, this quartzofeldspathic orthogneiss is penetratively foliated and lineated and is locally thinly layered (Fox and Rinehart, 1988). Layers are defined by slight differences in color index, not by variations in component minerals.

The orthogneiss of Anglin is a west-trending, elongate intrusion in the central part of the Okanogan metamorphic core complex (Cheney and others, 1982; Orr and Cheney, 1987; Fox and Rinehart, 1988; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988). All that can be said about the unit's age is that it intrudes the Tonasket Gneiss.

Tog.

Orthogneiss of Osoyoos (Triassic)--Chiefly medium- to coarse-grained granodioritic and tonalitic gneiss, with a narrow, discontinuous belt of fine-grained, mesocratic dioritic gneiss along its eastern border. Quartz, andesine, orthoclase, biotite, hornblende, and epidote are the principal constituents of the granodioritic and tonalitic rocks. Myrmekite, sphene, apatite, and magnetite are common accessory minerals. The dioritic rocks contain little or no quartz and more mafic minerals than the granodioritic and tonalitic gneiss, but are otherwise compositionally similar.

The orthogneiss of Osoyoos is characterized by igneous textures modified by cataclasis. The crushed, granulated, and recrystallized rocks are strongly foliated, linedated, and locally banded. Foliation is defined by the alignment of platy biotite, hornblende, and epidote crystals. Banding is the result of the segregation of felsic and mafic minerals. Both foliation and banding typically strike N45°W and dip 20° to 70° to the northeast.

The orthogneiss is a northwest-trending intrusion that straddles the Canadian border east of Osoyoos Lake (T. 40 N., R. 28 E.) (Daly, 1912; Krauskopf, 1938; Waters and Krauskopf, 1941; Fox, 1970, 1978). The unit intrudes the Kobau Formation and Anarchist Group. A slightly discordant U-Pb zircon age of 201.5 ± 2.2 Ma is reported from the orthogneiss of Osoyoos in British Columbia (Parkinson, 1985). It probably represents the crystallization age of the pluton. A K-Ar biotite age of 49.0 ± 1.5 Ma (Fox and others, 1976) indicates that post-deformational uplift and cooling of the intrusion did not occur until the middle Eocene.

Layered Metamorphic Rocks**pTbg_t, pTbgm_t**

Tonasket Gneiss (pre-Tertiary)--A heterogeneous assemblage of banded and migmatitic, amphibolite-facies quartzofeldspathic gneiss and schist, biotite-hornblende gneiss and schist, amphibolite, gneissic alaskite-pegmatite, and rare calc-silicate rocks (Snook, 1965; Fox, 1970, 1978; Rinehart and Fox, 1976; Cheney and others, 1982; Orr and Cheney, 1987; Gulick, 1987; K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). Chief components are plagioclase, K-feldspar, quartz, biotite, hornblende, garnet, and muscovite. Lithologic variations are principally the result of variations in the relative amount, arrangement, and grain size of these constituent minerals. The thickness of the laterally discontinuous layers ranges from less than 1 cm to a few meters.

The Tonasket Gneiss is herein subdivided into two informal map units: pTbg_t, banded gneiss; and pTbgm_t, banded mesocratic gneiss (K. F. Fox, Jr., and C. D. Rinehart, USGS, written commun., 1988). Unit pTbg_t consists chiefly of gray quartzofeldspathic gneiss with minor interlayers of amphibolite and biotite-hornblende gneiss and schist. Unit pTbgm_t is composed of black to dark greenish gray amphibolite and biotite-hornblende gneiss and schist with subordinate interlayers of gray quartzofeldspathic rocks.

The layered, heterogeneous nature of the gneiss, schist, and amphibolite, and the presence of thin interlayers of calc-silicate rocks has led most workers to believe that the Tonasket Gneiss was derived largely from metasedimentary and metavolcanic rocks (Waters and Krauskopf, 1941; Snook, 1965; Fox and others, 1976). However, Cheney and others (1982) and Orr and Cheney (1987) think that the Tonasket Gneiss is part of a compositionally zoned batholith.

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Three U-Pb zircon ages are reported from a single sample of the Tonasket Gneiss (Fox and others, 1976). They range from 87 to 100 Ma (Table 1). These ages should be regarded "as an estimate of the maximum time since either crystallization, recrystallization, or metamorphism resulted in lead loss or uranium gain by the zircon" (Fox and others, 1976, p. 1223). They represent a minimum age for the Tonasket Gneiss. Protolith age is unknown.

pTsc, pTmb

Metamorphic rocks near Bonaparte Lake (pre-Tertiary)--Dominantly dark-gray, fine- to medium-grained, muscovite-biotite schist, commonly with porphyroblasts of staurolite and/or garnet (pTsc); intercalated with thin beds of quartzite and amphibolite, and containing discontinuous pods and lenses of massive, fine- to medium-grained, white marble (pTmb).

These amphibolite-facies metamorphic rocks form a north-trending belt along the eastern border of the map area between Bonaparte Lake and the West Fork Sanpoil River (Pearson, 1967; Fox, 1973, 1978; Cheney, 1980; Cheney and others, 1982; Orr, 1985; Orr and Cheney, 1987; Rinehart and Greene, 1988). They extend east into the Republic 1:100,000-scale quadrangle. Rinehart and Greene (1988) believe that these amphibolite-facies metamorphic rocks grade into the greenschist-facies metasedimentary rocks of the Permian Anarchist Group(?). Cheney and others (1982) and Orr and Cheney (1987) think that the contact between the amphibolite-facies and greenschist-facies is abrupt and is marked by a fault. The latter workers believe that the amphibolite-facies rocks are part of the Okanogan metamorphic core complex.

Little is known about the age of the metamorphic rocks near Bonaparte Lake except that they are intruded by the Mount Bonaparte, Moses, and Wauconda plutons.

pTgn

Monzonitic and syenitic gneiss (pre-Tertiary)--Complexly foliated and sheared monzonitic and syenitic gneiss. This unit forms a narrow, discontinuous belt around the northern border of the Mount Bonaparte pluton (Krauskopf, 1938; Waters and Krauskopf, 1941; Fox, 1970, 1973, 1978); it consists of three distinct segments: (1) a 2-km-long elongate body straddling the Canadian border east of Osoyoos Lake; (2) a 15-km-long, west-northwest-trending belt along Tonasket Creek (T. 40 N., R. 28 E.) and the northern Eden Valley (T. 39 N., R. 29 E.); and (3) a narrow, 13-km-long, north-northeast-trending, arcuate strip between Bonaparte Lake and Myers Creek (T. 38 and 39 N., R. 30 E.). The western segment is chiefly mesocratic syenite gneiss with minor pyroxenite. The central segment is dominated by mesocratic monzonitic and syenitic gneiss. The eastern segment consists of mesocratic monzonitic gneiss. In general, the K-feldspar to plagioclase ratio and the mafic mineral content increase to the west.

Chief constituents of the gray, fine- to medium-grained monzonitic and syenitic gneiss are K-feldspar (perthitic orthoclase and microcline), plagioclase (oligoclase-andesine), and hornblende. Quartz generally occurs only as intergrowths with K-feldspar. Sphene and garnet are commonly conspicuous components of the rocks. Epidote, magnetite, apatite, and zircon are common accessory minerals. Segregation of the mafic and felsic minerals has imparted a banded appearance to the gneiss in places.

The monzonitic and syenitic gneiss is weakly to strongly foliated but not lineated. The foliation is defined by the subparallel orientation of hornblende crystals. Orientation of the foliation varies from planar to slightly curved to complexly swirled. Textures in the gneiss vary from xenomorphic-gneissic to strongly cataclastic. The gneiss is locally cut by a myriad of shear zones. The combination of swirled foliations and complex shears have rendered a chaotic appearance to the gneiss in places.

Chaotic dike swarms and irregular masses of pegmatite-alaskite cut the monzonitic and syenitic gneiss in many places, obscuring contact relations between the gneiss and surrounding rocks. Nevertheless, the following observations have been made (Krauskopf, 1938; Fox, 1973): (1) the mesocratic syenite gneiss and pyroxenite along the Canadian border interfinger with the orthogneiss of Osoyoos; (2) the monzonitic and syenitic gneiss in the central and eastern parts of the belt grade into Anarchist Group metasedimentary rocks and the Wauconda pluton; and (3) directionless granodiorite of the Mount Bonaparte pluton sharply cross-cuts the gneiss.

The origin of the monzonitic and syenitic gneiss is problematic, but Fox (1973) makes the following observations: (1) the gneiss forms a discontinuous belt along the northern border of the Mount Bonaparte pluton; (2) the gneiss grades into the orthogneiss of Osoyoos and greenschist-facies metasedimentary rocks of the Anarchist Group; and (3) the gneiss is much more alkalic in composition than the rocks that surround them. The gradational nature of the northern contact and the absence of magmatic features such as satellite dikes and xenoliths suggest that the monzonitic and syenitic gneiss formed by alkali metasomatism of the Anarchist Group and the orthogneiss of Osoyoos (Fox, 1973). The belt of monzonitic and syenitic gneiss may mark the northern border of the Okanogan metamorphic core complex.

The monzonitic and syenitic gneiss is cut by granodiorite of the Eocene-Paleocene Mount Bonaparte pluton. It has yielded K-Ar hornblende ages of 53.9 ± 1.6 Ma and 58.1 ± 1.7 Ma and fission-track ages of 63 ± 3 Ma (epidote) and 66 ± 7 Ma (sphene) (Table 1).

Other Metamorphic Rocks

Layered metamorphic rocks, complexes of mixed metamorphic and igneous rocks, and metamorphosed intrusions (orthogneiss) also form an extensive northwest-trending belt in the western part of the map area. The layered metamorphic rocks are a regionally metamorphosed package of pre-Jurassic sedimentary and volcanic rocks. The mixed metamorphic and igneous rocks formed either by deep burial, ultrametamorphism, and partial fusion (anatexis) of the layered metamorphic rocks (Hawkins, 1963, 1968; Menzer, 1983) or by injection of magma into the layered metamorphic rocks (V. R. Todd, USGS, written commun., 1988). The orthogneisses are metamorphosed or deformed Early Cretaceous to Late Triassic intrusions.

Meta-igneous Rocks

Kjog

Leader Mountain granodioritic gneiss (Cretaceous or Jurassic?)--Granodioritic gneiss composed of K-feldspar porphyroblasts, as much as 5 cm long, in a medium- to coarse-grained groundmass of plagioclase (oligoclase-andesine), K-feldspar (microcline and orthoclase), quartz, biotite, and hornblende (ferrohastingsite). The color index is typically between 10 and 20. Allanite and myrmekite are ubiquitous accessory minerals that are characteristic components of the gneiss. Other accessory minerals include apatite, sphene, ilmenite, leucoxene, magnetite, zircon, clinozoisite, and pistacite.

The Leader Mountain granodioritic gneiss is weakly to strongly foliated. Foliation is generally more pronounced near contacts with older rock units and is typically parallel to the foliation in the older rocks.

The Leader Mountain granodioritic gneiss is a syn-kinematic pluton that has been modified by late- or post-kinematic recrystallization and potassium metasomatism (Menzer, 1964, 1983). Most of the gneiss exhibits crystalloblastic textures, but relict igneous textures are locally preserved. The K-feldspar

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porphyroblasts are late metamorphic minerals that probably formed at the expense of plagioclase during potassium metasomatism (Menzer, 1964, 1983). The porphyroblasts are commonly aligned parallel to the foliation in the gneiss, but some have grown across the foliation.

The Leader Mountain granodioritic gneiss is a narrow, northwest-trending intrusion in the southwestern corner of the Oroville 1:100,000-scale quadrangle and the northwestern corner of the Omak 1:100,000-scale quadrangle (Menzer, 1964, 1982, 1983; Rinehart, 1981). In the map area the unit intrudes the gneissic trondhjemite of Tiffany Mountain. Contacts are typically gradational and are marked by zones of mixed rocks with varied compositions and textures. The Leader Mountain unit is cut by the Conconully pluton.

A Rb-Sr biotite age of 129.0 ± 1.8 Ma is reported for the Leader Mountain granodioritic gneiss (Table 1). Menzer (1970) believes it represents the magmatic crystallization age of the pluton. K-Ar hornblende and biotite ages of 98.5 ± 3.0 Ma and 90.1 ± 2.7 Ma, respectively, and a fission-track sphene age of 78 ± 8 Ma probably record the age of uplift and cooling of the gneiss (Menzer, 1970; Berry and others, 1976).

Kjog_w

Orthogneiss near Windy Peak (Cretaceous or Jurassic?)--Directionless to weakly foliated, fine- to medium-grained, leucocratic orthogneiss. The composition ranges from granodiorite to tonalite to quartz diorite (Hibbard, 1971). Biotite is the chief mafic mineral in the rocks; it is concentrated in schlieren-like masses. Igneous textures are locally preserved, but most of the gneiss exhibits a granular texture characterized by poorly formed crystal faces and little or no plagioclase zoning.

The unit covers approximately 5 km² on the eastern flank of Windy Peak and the western flank of Horseshoe Mountain (T. 40 N., R. 23 E.) (Hibbard, 1971; Rinehart, 1981). The orthogneiss near Windy Peak intrudes the Tillman Mountain tonalitic gneiss and grades into the Cathedral batholith and the Horseshoe Mountain pluton (Hibbard, 1971). It is compositionally and texturally similar to, and may be correlative with leucocratic orthogneiss in the gneissic trondhjemite of Tiffany Mountain to the south. These relations suggest that the age of the orthogneiss of Windy Peak is Late Cretaceous or Jurassic.

JTrog_t

Tillman Mountain tonalitic gneiss (Jurassic or Triassic?)--Medium- to coarse-grained tonalite and granodiorite composed of quartz, plagioclase (oligoclase-andesine), K-feldspar, biotite, and hornblende. The color index is approximately 25. Most of the unit is moderately to strongly foliated, but crystalloblastic textures are dominant. Cataclastic gneissose structures are common, and amphibolitic streaks and bands occur locally.

The Tillman Mountain tonalitic gneiss is a broad, northwest-trending intrusion between Sinlahekin Creek (T. 37 N., R. 24 E.) and the Canadian border (Goldsmith, 1952; Hibbard, 1962, 1971; Staatz and others, 1971; Rinehart, 1981). The eastern margin of the Tillman Mountain tonalitic gneiss grades into the Loomis pluton, generally over many tens of meters. The two units are compositionally and texturally similar, but the Tillman Mountain gneiss contains slightly more plagioclase and mafic minerals than the Loomis pluton, and the gneiss is generally moderately to strongly foliated and the pluton is directionless to weakly foliated. The Tillman Mountain tonalitic gneiss also exhibits gradational contacts with the North Fork Camp hybrid gneiss and the amphibolite-facies metamorphic rocks of the metamorphic complex of Conconully. It is cut by several younger intrusions, including the Similkameen, Horseshoe Mountain, and Bottle Spring plutons, the Cathedral batholith, and the South Fork quartz monzonite.

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The Tillman Mountain tonalitic gneiss has yielded discordant K-Ar hornblende and biotite ages of 173 ± 7 Ma and 96.7 ± 3.5 Ma, respectively (DGER unpublished data). These ages, the cross-cutting relationships with other intrusions, and the gradational relation with the Loomis pluton suggest that the Tillman Mountain tonalitic gneiss is an Early Jurassic or Late Triassic pluton that was cataastically deformed after crystallization (Hibbard, 1971).

Mzog_i

Meta-quartz diorite and metadiorite near Lemansky Lake (Mesozoic)--Fine- to medium-grained meta-quartz diorite and metadiorite composed of plagioclase (oligoclase-andesine), hornblende, biotite, epidote, and various amounts of quartz. Textures vary from xenomorphic-granular to granoblastic. Sericitization and saussuritization of plagioclase and chloritization of biotite are common.

The unit forms several small intrusions southeast of Lemansky Lake (T. 37 N., R. 26 E.). It is strongly foliated. The foliation in the gneiss is generally parallel to the foliation in the country rocks it intrudes, indicating that it is a pre- or syn-kinematic intrusion.

The age the meta-quartz diorite and metadiorite near Lemansky Lake is unknown. Because it cuts the Anarchist Group, it must be post-Middle Permian. A Mesozoic age is tentatively assigned.

Mzog_s

Granodioritic gneiss of Salmon Creek (Mesozoic)--Gneiss ranging in composition from quartz monzonite to diorite, but predominantly granodiorite. Some of the gneiss is equigranular, but most is porphyroblastic. The porphyroblastic rocks are composed of tabular, anhedral K-feldspar crystals, as much as 5 cm long, in a medium-grained groundmass of quartz, feldspar, and mafic minerals. Hornblende and biotite compose 15 to 25 percent of the rocks. Composition and texture of the gneiss commonly vary over short distances.

This granodioritic gneiss forms a narrow, northwest-trending belt along Salmon Creek and the North Fork Salmon Creek near Conconully (Rinehart and Fox, 1976; Rinehart, 1981). Most of the unit is moderately to strongly foliated, and some is strongly layered. Foliation and layering generally strike northwest, parallel to the regional structures in the surrounding metasedimentary and metavolcanic rocks.

Relict zoned plagioclase crystals and locally preserved intrusive contacts indicate that the granodioritic gneiss of Salmon Creek is a metamorphosed plutonic body that intruded the metamorphic complex of Conconully (Rinehart, 1981). Metamorphic fabrics and structures are parallel in the orthogneiss and the surrounding country rocks, indicating that the orthogneiss was emplaced before or during regional metamorphism. Because the age of intrusion is essentially unknown, a Mesozoic age is tentatively assigned.

Mixed Metamorphic and Igneous Rocks

Kjmi_t

Gneissic trondhjemite of Tiffany Mountain (Cretaceous or Jurassic?)--A heterogeneous unit composed of leucocratic trondhjemite and quartz dioritic gneiss interlayered with biotite-hornblende gneiss and schist, amphibolite, and calc-silicate rocks. Schist, amphibolite, and calc-silicate rocks form

discontinuous layers, inclusions, schlieren, and wisps within the trondhjemite and quartz dioritic gneisses. Layers range from less than 1 m to tens of meters thick. They are commonly isoclinally folded and complexly swirled.

The trondhjemite gneiss in the gneissic trondhjemite of Tiffany Mountain is weakly to moderately foliated, medium to coarse grained, and leucocratic. Sparse clots of recrystallized biotite and hornblende make up approximately 5 percent of the rocks. The quartz dioritic gneiss is more strongly foliated and more mafic (color index 20-25) than the trondhjemite gneiss. Both exhibit igneous textures modified by strain and recrystallization.

This unit forms a northwest-trending belt along the western border of the Oroville 1:100,000-scale quadrangle that extends west and south into the adjacent Robinson Mtn., Twisp, and Omak 1:100,000-scale quadrangles (Goldsmith, 1952; Hawkins, 1968; Rinehart, 1981; V. R. Todd, USGS, written commun., 1988; A. M. Frey, University of Pittsburgh, written commun., 1988; J. R. Wilson, formerly USGS, written commun., 1988).

K-Ar biotite ages reported from the gneissic trondhjemite of Tiffany Mountain range from 94.1 ± 0.7 to 104.5 ± 0.8 Ma (V. R. Todd, USGS, written commun., 1988). All are apparently metamorphic ages.

KJmi_x

Tiffany complex (Cretaceous or Jurassic?)--An assemblage of metadiorite, meta-quartz diorite, metagabbro, and minor amphibolite that is riddled with small bodies of directionless, leucocratic quartz monzonite and granodiorite.

The metadiorite, meta-quartz diorite, metagabbro, and amphibolite in the Tiffany complex are directionless to weakly foliated, fine- to coarse-grained rocks composed of plagioclase (labradorite-andesine), hornblende, biotite, and minor quartz. Accessory minerals include apatite, magnetite, sphene, and epidote. Mafic minerals typically form 20 to 35 percent of the rocks. Microscopic textures in the metadiorite, meta-quartz diorite, and metagabbro show a progressive development from granoblastic to porphyroblastic to igneous-appearing, suggesting formation by recrystallization. The composition of the rocks and the presence of minor amphibolite bodies within them suggest derivation from an amphibolitic source rock. The absence of layering in the rocks indicates "... derivation from basic igneous material rather than from basic sediments" (Goldsmith, 1952, p. 252).

The leucocratic quartz monzonite and granodiorite in the Tiffany complex are directionless, medium- to coarse-grained rocks composed of quartz, microcline, plagioclase, biotite, and hornblende. Mafic minerals generally form less than 10 percent of rocks. Microcline is commonly perthitic and plagioclase, is locally antiperthitic, indicating that microcline has replaced plagioclase. The leucocratic quartz monzonite and granodiorite form dike-like bodies and small masses within the metadiorite, meta-quartz diorite, and metagabbro. Uniform compositions of the quartz monzonite and granodiorite bodies over wide areas and sharp contacts between the leucocratic rocks and the metadioritic rocks suggest that the leucocratic rocks intruded the metadioritic rocks. Crystalloblastic textures in the leucocratic rocks indicate that intrusion occurred before or during recrystallization of the metadioritic rocks.

The Tiffany complex forms a 60-km², northwest-trending mass between Muckamuck Pass (T. 36 N., R. 24 E.) and Rock Mountain (T. 37 N., R. 23 E.) (Goldsmith, 1952; Rinehart, 1981). The complex is intruded by the Conconully and Bottle Spring plutons. It grades into the gneissic trondhjemite of Tiffany Mountain and the Leader Mountain granodioritic gneiss. The contact with the metamorphic complex of Conconully to the east is sharp. The absence of a strong structural fabric in the Tiffany complex suggests that it formed after regional dynamothermal metamorphism of the metamorphic complex of Conconully. Therefore, a Cretaceous or Jurassic age is suspected.

Jmi_n

North Fork Camp hybrid gneiss (Jurassic?)--Granitoid rocks with a wide variety of compositions and textures. The unit is an elliptical, northeast-trending body along the North Fork Toats Coulee Creek (T. 39 N., R. 24 E.) (Hibbard, 1971; Rinehart and Fox, 1972; Rinehart, 1981). The central and western parts of the North Fork Camp hybrid gneiss are gneissic and migmatitic; the eastern part is directionless and porphyritic. Compositions range from tonalite to quartz monzonite. Principal constituents are plagioclase (oligoclase-andesine), quartz, microcline, biotite, and hornblende. Accessory minerals include epidote, chlorite, magnetite, sphene, and apatite. Microcline forms phenocrysts as much as 2 cm long in the porphyritic rocks.

The North Fork Camp hybrid gneiss grades into the Tillman Mountain tonalitic gneiss, the South Fork quartz monzonite, and the Bowers quartz diorite. Hibbard (1971) thought that the North Fork Camp unit formed by injection of the South Fork quartz monzonite and possibly the Bowers quartz diorite into zones of active cataclasis and recrystallization in the older Tillman Mountain tonalitic gneiss. Discordant K-Ar hornblende and biotite ages of 170 ± 5 Ma and 151 ± 5 Ma, respectively, are reported for the unit (Rinehart and Fox, 1972). The radiometric ages and cross-cutting relations suggest that formation of this hybrid unit occurred some time in the Early Jurassic.

Layered Metamorphic Rocks**pJhm_x, pJmb_x**

Metamorphic complex of Conconully, heterogeneous metamorphic rocks (pre-Jurassic)--A heterogeneous assemblage of quartzofeldspathic schist and gneiss, amphibolite, quartzite, calc-silicate rocks, and marble. Quartzofeldspathic schist and gneiss, quartzite, and amphibolite (pJhm_x) are the principal constituents. Calc-silicate rocks and marble generally form thin, discontinuous interbeds within the quartzofeldspathic rocks, but one 7-km-long, northwest-trending body of marble (pJmb_x) crops out along the south side of the North Fork Salmon Creek. Sillimanite and almandine in the pelitic and quartztic rocks, labradorite-bytownite and hornblende in the calcareous and amphibolitic rocks, and green spinel and olivine in the marble indicate that the metamorphic complex of Conconully reached temperatures and pressures characteristic of the almandine amphibolite facies (Goldsmith, 1952; Menzer, 1964, 1983). Contact metamorphism by younger intrusions has locally modified the schistose rocks to hornfels and granofels.

Although the amphibolite-facies metamorphic rocks of the metamorphic complex of Conconully are foliated and recrystallized, primary textures and structures are locally preserved. Foliation and bedding are typically parallel. They generally strike north-northwest or north-northeast and dip steeply. Gently plunging folds with north-northwest-trending axes are common. Most are overturned to the northeast, and some are recumbent.

Garnetiferous alaskite and pegmatite dikes, sills, and irregular masses cut this metamorphic complex along Salmon Creek, on Funk Mountain (sec. 19, T. 36 N., R. 25 E.), and on the southernmost spur of Schallow Mountain (T. 35 N., R. 25 E.). Dikes and sills of metamorphosed hypabyssal intrusive rocks, probably equivalent to unit Mzi, cut the complex along the east-flowing segment of Sinlahekin Creek (T. 37 N., R. 25 E.).

The amphibolite-facies metamorphic rocks of the metamorphic complex of Conconully form a northwest-trending belt between Sinlahekin Creek (T. 37 N., R. 24 E.) and the southern border of the map area (Rinehart and Fox, 1976; Rinehart, 1981). The complex extends southeast into the Omak 1:100,000-scale quadrangle for an additional 35 km. It is equivalent to the Salmon Creek schists and gneisses of Goldsmith (1952) and Menzer (1964, 1983). The unit apparently grades to the northeast

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into greenschist-facies phyllite and metasiltstone (R mm_x) in the metamorphic complex of Conconully (Goldsmith, 1952; Rinehart and Fox, 1976). Along Sinlahekin Creek, the amphibolite-facies rocks are intruded by a small pluton that is thought to be the southern extension of the Late Triassic(?) Loomis pluton. These relations suggest that part of the metamorphic complex of Conconully is Late Triassic in age and part is probably older. However, the lack of stratigraphic marker horizons in the metamorphic complex of Conconully, as well as the recrystallized and deformed nature of the rocks makes correlation with lower grade metamorphic rocks in the region difficult. For these reasons, a pre-Jurassic age is tentatively assigned.

pJhm

Heterogeneous metamorphic rocks near Toats Coulee Creek (pre-Jurassic)--Interbedded quartzofeldspathic schist and gneiss, quartzite, calc-silicate rocks, marble, and amphibolite; distinctly layered, strongly foliated, and locally migmatitic. They are hornfelsic or granofelsic in places.

The unit crops out (1) along the Middle and South Forks of Toats Coulee Creek (T. 39 N., R. 24 E.); (2) northwest of Chopaka Mountain (T. 40 N., R. 24 E.); and (3) in Horseshoe Basin (T. 40 N., R. 23 E.) (Hibbard, 1971; Staatz and others, 1971; Rinehart, 1981; Menzer, 1983). The heterogeneous metamorphic rocks near Toats Coulee Creek are compositionally and structurally similar to the amphibolite-facies metamorphic rocks in the metamorphic complex of Conconully and may be correlative with them. They are intruded by the Horseshoe Mountain pluton, the South Fork quartz monzonite, the Similkameen pluton, the Tillman Mountain tonalitic gneiss, and the Loomis pluton. These cross-cutting relations indicate that the minimum age of the heterogeneous metamorphic rocks near Toats Coulee Creek is Triassic.

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Table 1. Radiometric age data, Oroville 1:100,000 quadrangle.

Map No.	Sample No.	Unit	Map Symbol	Location	Method	Material	Age (Ma)	Reference
1	L-498-A	Loomis pluton, granodiorite	JR igd ₁	NW/4 SE/4 sec. 34, T. 39 N., R. 25 E.	K-Ar	hornblende biotite	194 +/- 6 179 +/- 5	Rinehart and Fox (1972) ¹
2	CG-10	Chopaka intrusive complex, metagabbro	TR Pnib _C	NW/4 NW/4 sec. 24, T. 40 N., R. 24 E.	K-Ar	actinolitic hornblende	190.5 +/- 15.6	Hibbard (1971) ²
3	L-618	Similkameen pluton, granodiorite	Jia _S	48°58.4'N, 119°39.4'W	K-Ar	hornblende biotite	177.2 +/- 5.3 70.9 +/- 2.1	Engels (1971) ³
						hornblende biotite	146.1 +/- 4.8 76.6 +/- 2.3	
4	3923246e	Tillman Mountain tonalitic gneiss	JR ogt	SE/4 NW/4 sec. 24, T. 39 N., R. 23 E.	K-Ar	hornblende biotite	173 +/- 7 96.7 +/- 3.5	DGER unpublished data, this report ⁴
5	L-301	Similkameen pluton, shonkinite	Jik _S	48°59.4'N., 119°32.9'W	K-Ar	hastingsite biotite	170.9 +/- 5.1 69.9 +/- 2.1	Engels (1971) ³
6	----	Similkameen pluton, granodiorite	Jia _S	Location not given	Rb-Sr	isochron	170.5 +/- 5.0	Buddington and Burmester (1990) ⁵
7	L-591	North Fork Camp hybrid gneiss	Jm _n	SW/4 SW/4 sec. 13, T. 39 N., R. 24 E.	K-Ar	hornblende biotite	170 +/- 5 151 +/- 5	Rinehart and Fox (1972) ¹
8	L-277Y	Kobau Formation	TR Pnmt _k	48°59.3'N., 119°33.4'W	K-Ar	hornblende biotite	166.7 +/- 5.0 74.8 +/- 2.2	Fox and others (1975) ⁶
9	3924266C	South Fork quartz monzonite	Jigm _S	NE/4 SW/4 sec. 26, T. 39 N., R. 24 E.	K-Ar	hornblende biotite	162 +/- 7.0 131 +/- 5.0	DGER unpublished data, this report ⁴
10	L-620R	Ellemeham Formation, fenitized greenstone	Jmv _e	48°57.8'N., 119°31.1'W	K-Ar	biotite	157.4 +/- 4.7	Engels and others (1976)
11	L-589C	Similkameen pluton, granodiorite	Jia _S	48°59.1'N., 119°36.9'W	K-Ar	hornblende biotite	155.5 +/- 4.7 83.4 +/- 2.5	Fox and others (1975) ⁶
12	C-246-D	Blue Goat pluton, granodiorite	JR igd _b	NW/4 SW/4 sec. 9, T. 36 N., R. 25 E.	K-Ar	hornblende biotite	141.8 +/- 8.2 99.3 +/- 3.0	Rinehart and Fox (1976) ⁸
13	L-277Z	Similkameen pluton, pyroxenite	Jik _S	48°59.4'N., 119°33.2'W	K-Ar	biotite	140.9 +/- 4.2	Fox and others (1975) ⁶
14	L-277W	Similkameen pluton, pegmatite-alaskite dike	(not shown on map)	48°59.4'N., 119°33.3'W	K-Ar	muscovite	135.7 +/- 4.1 (1975) ⁶	Fox and others
15	CK-5	Leader Mountain granodioritic gneiss	KJog ₁	48°31'N., 119°55'W	RbSr fission-track	isochron sphene	129.0 +/- 1.8 78 +/- 8	Menzer (1970) ⁹
16	3927188f	Whisky Mountain pluton, mesocratic quartz diorite	KJii _w (not shown on map)	SW/4 NW/4 sec. 18, T. 39 N., R. 27 E.	K-Ar	hornblende	119 +/- 5	DGER unpublished data, this report ⁴

Table 1. Radiometric age data, Oroville 1:100,000 quadrangle (continued).

Map No.	Sample No.	Unit	Map Symbol	Location	Method	Material	Age (Ma)	Reference
17	L-451C	Anderson Creek pluton, granodiorite	KJigd _a	48°55.6'N., 119°40.7'W	K-Ar	hornblende biotite	115.6 +/- 3.0 100.1 +/- 3.0	Engels and others (1976) ¹
18	AC-39	Anderson Creek pluton, granodiorite	KJigd _a	NE/4 sec. 24, T. 40 N., R. 24 E.	K-Ar	biotite	106.5 +/- 6.8	Hibbard (1971) ²
19	402336lh	Horseshoe Mountain pluton, quartz monzonite	Kiqm _h	NE/4 NE/4 sec. 36, T. 40 N., R. 23 E.	K-Ar	biotite hornblende	103 +/- 4 94.6 +/- 4.6	DGER unpublished data, this report ⁴
20	O-176E	Tonasket Gneiss, banded gneiss	pTog _t	48°46.9'N., 119°18.8'W	Pb ²⁰⁷ /U ²³⁵ Pb ²⁰⁸ /Th ²³² Pb ²⁰⁶ /U ²³⁸	zircon zircon zircon	100.0 94.0 87.3	Fox and others (1976) ¹⁰
21	T-152	Leader Mountain granodioritic gneiss	KJog ₁	48°36.7'N., 119°56.8'W	K-Ar	hornblende biotite	98.5 +/- 3.0 90.1 +/- 1.7	Berry and others (1976) ¹¹
22	3726084a	Aeneas Creek pluton, quartz monzonite	Kia _a	SW/4 SE/4 sec. 8, T. 37 N., R. 26 E.	K-Ar	biotite hornblende	98.3 +/- 3.6 92.3 +/- 4.3	DGER unpublished data, this report ⁴
23	3723242g	Lone Frank pluton, quartz diorite	Kiq _l	NE/4 NE/4 sec. 24, T. 37 N., R. 23 E.	K-Ar	biotite hornblende	96.9 +/- 3.6 92.7 +/- 4.9	DGER unpublished data, this report ⁴
24	G-124	Orthogneiss of Anglin	pTog _a	48°41'N., 119°23.5'W (approximate location)	Pb-alpha	zircon	95 (suspect age)	Larsen and others (1958) ¹²
25	T-153	Gneissic trondhjemite of Tiffany Mountain	KJmit _t	48°39.8'N., 119°57.9'W	K-Ar	hornblende biotite	93.5 +/- 2.8 88.5 +/- 2.7	Berry and others (1976) ¹¹
26	C-139	Aeneas Creek pluton, quartz monzonite	Kia _a	SW/4 SE/4 sec. 8, T. 37 N., R. 26 E.	K-Ar	biotite	92.7 +/- 6.6	Rinehart and Fox (1976) ⁸
27	G-125	Orthogneiss of Anglin(?)	pTog _{a?}	48°38'N., 119°17'W (location uncertain)	Pb-alpha	zircon	92 (suspect age)	Larsen and others (1958) ¹²
28	CK-1	Conconully pluton, granodiorite	Kigd _c	48°31'N., 119°52'W	Pb-alpha fission-track fission-track	zircon apatite sphene	90 +/- 20 89 +/- 9 84 +/- 8	Menzer (1970) ⁹
29	TM-6	Bottle Spring pluton, monzogranite	Kia _b	SE/4 NW/4 sec. 27 T. 38 N., R. 23 E.	K-Ar	biotite	89.2 +/- 0.6	V. R. Todd (USGS, written commun., 1988) ¹³
30	CK-1 and CK-4	Conconully pluton	Kigd _c	48°31'N., 119°52'W and 48°20'N., 119°40'W (Omak 1:100,000 quadrangle)	Rb-Sr isochron	apatite, biotite, muscovite, wall rock	81.8 +/- 0.8	Menzer (1970) ⁹
31	T-156	Conconully pluton, granodiorite	Kigd _c	48°35.7'N., 119°52.1'W	K-Ar	hornblende biotite	81.2 +/- 2.4 78.8 +/- 2.4	Berry and others (1976) ¹¹

Table 1. Radiometric age data, Oroville 1:100,000 quadrangle (continued).

Map No.	Sample No.	Unit	Map Symbol	Location	Method	Material	Age (Ma)	Reference
32	C-555	Conconully pluton, quartz monzonite	Kigd _c	NW/4 NW/4 sec. 13 T. 35 N., R. 24 E.	K-Ar	hornblende biotite	72.8 +/- 4.6 62.5 +/- 2.2	Rinehart and Fox (1976) ⁸
33	O-131	Unnamed monzonitic and syenitic gneiss	pTgn	48°56.6'N, 119°18.5'W	fission-track fission-track	sphene epidote	66 +/- 7 63 +/- 3	Naeser (1970) ¹⁴
					K-Ar	hornblende	58.1 +/- 1.7	Fox and others (1976) ¹⁰
34	O-38A	Mount Bonaparte pluton granodiorite	EB _a iab _b	48°54.1'N, 119°18.7'W	fission-track fission-track	allanite apatite	59 +/- 2 53 +/- 5	Naeser (1970) ¹⁴
					K-Ar	biotite	54.8 +/- 1.7	Fox and others (1976) ¹⁰
35	O-36A	Mount Bonaparte pluton, granodiorite	EB _a iab _b	48°53.3'N., 119°17.0'W	Fission-track Fission-track	allanite apatite	59 +/- 6 51 +/- 5	Naeser (1970) ¹⁴
					K-Ar K-Ar	muscovite biotite	49.8 +/- 1.6 49.3 +/- 1.6	Fox and others (1976) ¹⁰
36	O-296D	Unnamed monzonitic and syenitic gneiss	pTgn	48°51.6'N., 119°01.3'W	K-Ar	hornblende biotite	53.9 +/- 1.6 50.0 +/- 1.5	Fox and others (1976) ¹⁰
37	O-37A	Mount Bonaparte pluton, pegmatite	Not shown on map	48°54.4'N., 119°17.5'W	K-Ar	muscovite (-20 mesh)	53.8 +/- 1.6 49.0 +/- 2.2	Fox and others (1976) ¹⁰
						muscovite (5 mm discs)	51.2 +/- 1.6 50.8 +/- 1.6	
38	L-147	Porphyritic dacite plug	Eida	SE/4 sec. 24, T. 40 N., R. 26 E.	K-Ar	hornblende	52.1 +/- 2.3	Rinehart and Fox (1972) ¹
39	L-590	Porphyritic dacite plug	Eida	SE/4 sec. 12, T. 40 N., R. 26 E.	K-Ar	hornblende	51.4 +/- 2.6	Rinehart and Fox (1972) ¹
40	MK86-6-3	Diorite plug	Eid	SE/4 NW/4 sec. 14, T. 37 N., R. 24 E.	K-Ar	hornblende	49.5 +/- 2.7	DGER unpublished data, this report ⁴
41	O-176D	Tonasket Gneiss, banded gneiss	pTbg _t	48°46.9N., 119°18.8W	K-Ar	hornblende	49.3 +/- 1.7	Fox and others (1976) ¹⁰
42	L-657	Porphyritic dacite flow	Evd	NW/4 sec. 21, T. 38 N., R. 27 E.	K-Ar	hornblende	49.1 +/- 1.8	Rinehart and Fox (1972) ¹

Table 1. Radiometric age data, Oroville 1:100,000 quadrangle (continued).

Map No.	Sample No.	Unit	Map Symbol	Location	Method	Material	Age (Ma)	Reference
43	MK87-8-51	Porphyritic dacite flow	Evd	NE/4 NW/4 sec, 28, T. 37 N., R. 24 E.	K-Ar	whole rock	47.3 +/- 2.0	DGER unpublished data, this report ⁴
44	C-550	Porphyritic dacite flow	Evd	NE/4 NW/4 sec. 15, T. 36 N., R. 26 E.	K-Ar	hornblende	45.1 +/- 2.0	Rinehart and Fox (1976) ⁸
45	C-559	Porphyritic dacite flow	Evd	48°41.2'N., 119°45.5'W	K-Ar	hornblende	42.9 +/- 1.3	Berry and others (1976) ¹¹

1 Rinehart and Fox (1972): Constants not reported

2 Hibbard (1971): $\lambda_e = 0.585 \times 10^{-10}/\text{yr}$; $\lambda_\beta = 4.72 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.19 \times 10^{-4}$

3 Engels (1971): Constants not reported

4 DGER unpublished data, this report: $\lambda_e + \lambda_{e'} = 0.581 \times 10^{-10}/\text{yr}$; $\lambda_\beta = 4.962 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.19 \times 10^{-4}$

5 Buddington and Burmester (1990): Constants not reported

6 Fox and others (1975): $\lambda_e = 0.585 \times 10^{-10}/\text{yr}$; $\lambda_\beta = 4.72 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.19 \times 10^{-4}$

7 Engels and others (1976): constants not reported

8 Rinehart and Fox (1976): constants not reported

9 Menzer (1970): $\lambda_f = 7.03 \times 10^{-17}/\text{yr}$; $^{87}\text{Rb} t_{1/2} = 5 \times 10^{-10}\text{yr}$; normalized to $^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$ 10 Fox and others (1976): $\lambda_e = 0.585 \times 10^{-10}/\text{yr}$; $\lambda_\beta = 4.72 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.19 \times 10^{-4}$ 11 Berry and others (1976): $\lambda_e = 0.585 \times 10^{-10}/\text{yr}$; $\lambda_\beta = 4.72 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.19 \times 10^{-4}$

12 Larsen and others (1958): constants not reported

13 V. R. Todd (USGS, written commun., 1988): constants not reported

14 Naeser and others (1970): $\lambda_f = 6.9 \times 10^{-17}/\text{yr}$

Table 2. Major oxide geochemistry data, Oroville 1:100,000-scale quadrangle. Analyses by XRF Lab, Department of Geology, Washington State University. All analyses normalized on a volatile-free basis to 100% with FeO* = total Fe as FeO

SAMPLE NUMBER	MAP UNIT	SUBSECTION	SEC	TWP	RGE	SiO ₂	Al ₂ O ₃	TiO ₂	FeO*	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅
3824217C	Evd	NW/4 SW/4	21	38	24E	62.08	16.71	0.73	5.50	0.74	4.39	3.89	2.75	3.26	0.33
3824202F	Evd	SE/4 NE/4	20	38	24E	62.44	16.71	0.71	5.35	0.08	4.68	3.62	2.15	3.62	0.32
MK870848	Evd	SW/4 SW/4	21	37	24E	66.76	16.60	0.50	3.26	0.06	3.72	1.62	2.82	4.48	0.18
MK870847	Evd	SE/4 SE/4	21	37	24E	63.95	17.07	0.65	4.47	0.09	5.72	2.41	1.89	3.47	0.28
MK870851	Evd	NE/4 NW/4	28	37	24E	64.83	16.15	0.56	3.74	0.07	4.95	2.93	2.61	3.95	0.21
MK870840	Ev	SW/4 NW/4	12	36	25E	52.87	14.38	0.84	7.80	0.16	8.33	10.94	2.18	2.21	0.28
MK870841	Ev	NE/4 SE/4	11	36	25E	71.94	15.42	0.42	2.13	0.03	3.01	0.52	3.67	2.70	0.16
MK870842	Ev	SE/4 SE/4	10	36	25E	68.17	15.77	0.48	2.81	0.06	2.83	1.78	3.92	3.99	0.19
MK870843	Ev	NE/4 NE/4	15	36	25E	70.15	15.92	0.42	2.37	0.05	1.88	1.43	3.99	3.64	0.15
MK870844	Ev	SE/4 SE/4	10	36	25E	68.69	15.79	0.47	2.73	0.05	3.05	1.50	3.08	4.45	0.17
MK8663	Eid	SW/4 NE/4	14	37	24E	62.49	16.64	0.68	4.98	0.09	5.13	2.67	2.28	4.42	0.31
MK8665	Eid	SE/4 NW/4	25	37	24E	63.35	16.78	0.63	4.56	0.08	2.94	2.39	3.44	5.26	0.24

Table 3. Trace element geochemistry data, Oroville 1:100,000-scale quadrangle; analyses by XRF, Washington State University. All analyses in parts per million.

SAMPLE	MAP UNIT	NI	CR	SC	V	BA	RB	SR	ZR	Y	NB	GA	CU	ZN
3824217C	Evd	32	42	13	105	1712	61	653	175	19	0.8	23	0	93
3824202F	Evd	25	48	7	106	1483	48	1125	181	18	9.0	20	5	82
MK870848	Evd	13	12	11	66	1252	56	754	146	14	7.7	17	11	79
MK870847	Evd	27	35	14	86	1662	44	1018	159	16	9.0	17	20	69
MK870851	Evd	52	73	11	93	1372	51	1039	151	12	7.0	19	28	60
MK870840	Ev	149	686	27	212	966	48	492	102	18	9.8	12	41	75
MK870841	Ev	23	19	7	40	1937	107	362	147	15	11.0	17	11	45
MK870842	Ev	25	17	8	49	1424	117	728	154	15	11.0	19	17	53
MK870843	Ev	19	21	7	47	1483	100	831	164	15	10.6	16	9	53
MK870844	Ev	19	13	8	44	1347	77	985	168	15	10.0	17	19	52