GEOLOGIC MAP OF THE NESPELEM 1:100,000 QUADRANGLE, WASHINGTON

Compiled by

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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES

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This revised version supersedes the previous release, which is no longer available.

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

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Brian Boyle - Commissioner of Public Lands
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Division of Geology and Earth Resources
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CONTENTS

ILLUSTRATIONS

TABLE

GEOLOGIC MAP OF THE NESPELEM 1:100,000 QUADRANGLE, WASHINGTON

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Nancy L. Joseph

INTRODUCTION

The Nespelem quadrangle is one of sixteen complete or partial 1:100,000-scale quadrangles that cover the northeast quadrant of Washington State (north of 47°15'N latitude and east of 120°30'W longitude) (Fig. 1). Geologic maps of these quadrangles have been compiled by Washington Division of Geology and Earth Resources (DGER) geologists and are the principal data sources for the new 1:250,000-scale geologic map of the northeast quadrant of Washington, which is in preparation. Fourteen of these quadrangles will be released as DGER open-file reports (listed below); the Chelan and Wenatchee quadrangles have not been open-filed because they have been published by the U.S. Geological Survey (USGS) (Tabor and others, 1982, 1987).

Literature review and preliminary compilation of the Nespelem quadrangle began in 1986. Between 1986 and 1989, new reconnaissance geologic mapping was performed by the DGER staff in areas where previous geologic mapping was either inadequate or lacking. New geologic mapping was also acquired through a DGER graduate student mapping program. Figure 2 shows sources of geologic map data used for compilation of the Nespelem quadrangle.

Age assignments of geologic units in the Nespelem 1:100:000-scale quadrangle were made following the flow chart in Figure 3. The geologic time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador, 1985) was used, with slight modifications of the Eocene-Oligocene and Pliocene-Pleistocene boundaries (Armentrout and others, 1983; Prothero and Armentrout, 1985; Montanari and others, 1985; Aguirre and Pasini, 1985). All known published radiometric ages from the Nespelem 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 when data were available. Whole-rock geochemical data and the total alkali-silica (TAS) diagram (Zanettin, 1984) were the basis for assigning names to volcanic rocks for which geochemical data were available. The term metamorphic rocks is limited to rocks of amphibolite grade or higher. Rocks of greenschist grade or lower are included in sedimentary, volcanic, or intrusive rock packages; greenschist-grade rocks are designated as metasedimentary or metavolcanic rocks.

A mixture of formal, informal, and unnamed geologic units is shown on the map (Plate I). Unit symbols provide information about the age, lithology, and name (if any) of the units: upper-case letters indicate age; lower-case letters indicate lithology; and subscripts identify named units. Example: the granite of Deadhorse Creek is an Eocene intrusive granite and is shown with the symbol Eig_{dh}.

DGER Northeast Quadrant Open-file Reports

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

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

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.

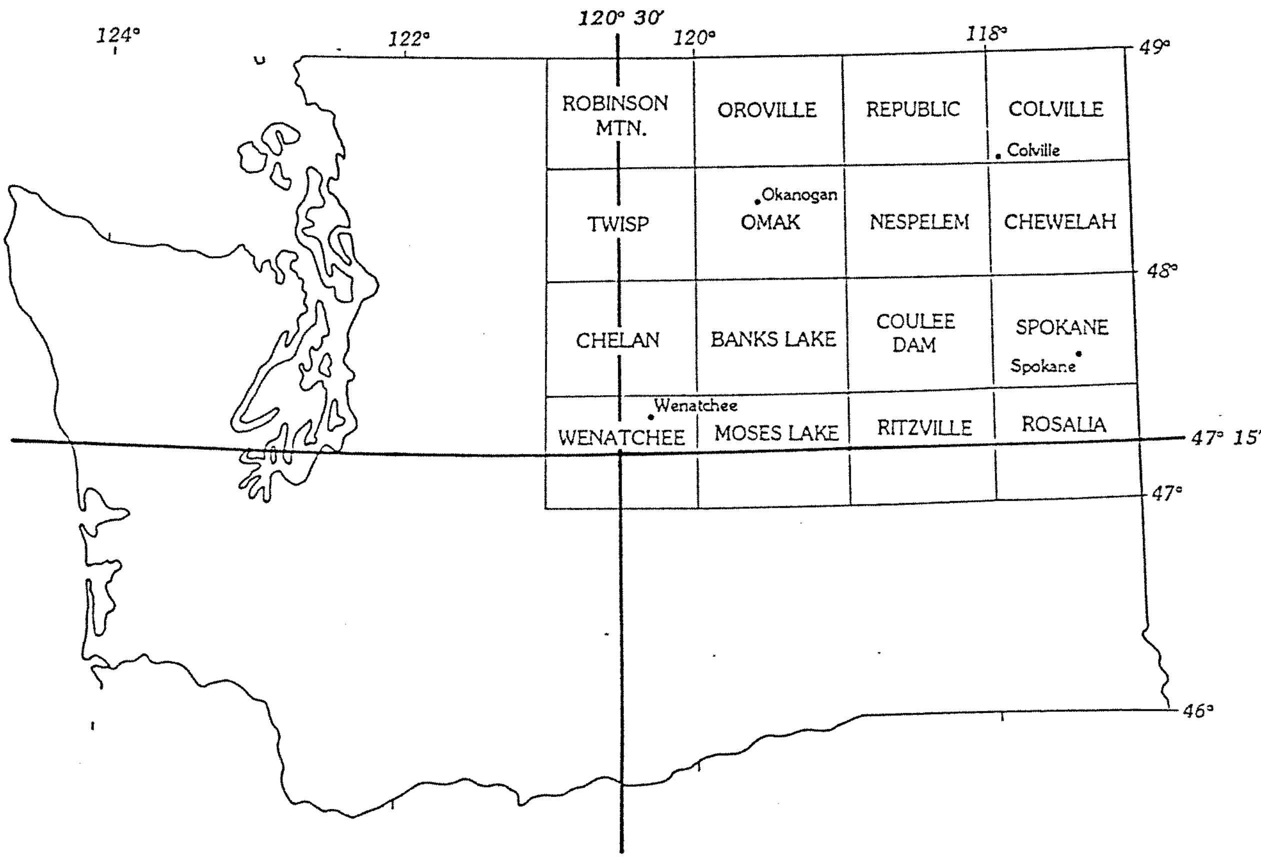


Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Explanation for Figure 2 (see facing page)

1. Abrams, 1980, plate 1, scale 1:24,000.
2. Atwater, 1986, plate 2, scale 1:62:500.
3. Atwater and Rinehart, 1984, plate 2, scale 1:100,000.
3a. Atwater, B. F.; Rinehart, C. D., 1989, written commun., scale 1:100,000.
4. Becraft, 1966, 1 sheet, scale 1:62,500.
5. Campbell and Loofbourow, 1962, plate 1, scale 1:36,000.
6. Campbell and Raup, 1964, 1 sheet, scale 1:48,000.
7. Carlson, 1984, plate 1, 1:48,000.
8. Colville Confederated Tribes Geology Department, unpublished mapping, scale 1:24,000.
9. Fullmer, 1986, plate 1, 1:24,000.
10. Hanson, 1979, 1 sheet, scale 1:250,000.
11. Holder, W. R.; Holder, G. M., 1989, written commun., scale 1:48,000.
12. Janzen, 1981, plate 1, scale 1:25,000.
13. Kiver, E. P.; Stradling, D. F., 1986, written commun., scale 1:24,000.
14. Lindsey, 1988, plate 5, scale 1:24,000.
15. Moye, 1984, plate 1, scale 1:62:500.
16. Moye, 1987, figure 2, scale 1:393,696
17. Orlean, 1981, plate 1, scale 1:25,000.
18. Smith, 1982, plate 1, scale 1:25,000.
19. Smith, M. T., 1989, DGER unpublished mapping, scale 1:24:000.
20. Smith, M. T., 1990, DGER unpublished mapping, scale 1:12,000.
21. Snook, J. R.; and others, 1987, written commun., scale, 1:48,000.
22. Staatz, 1964, plate 1, scale 1:62,500.
23. Swanson and others, 1979, plate 1, scale 1:250,000.

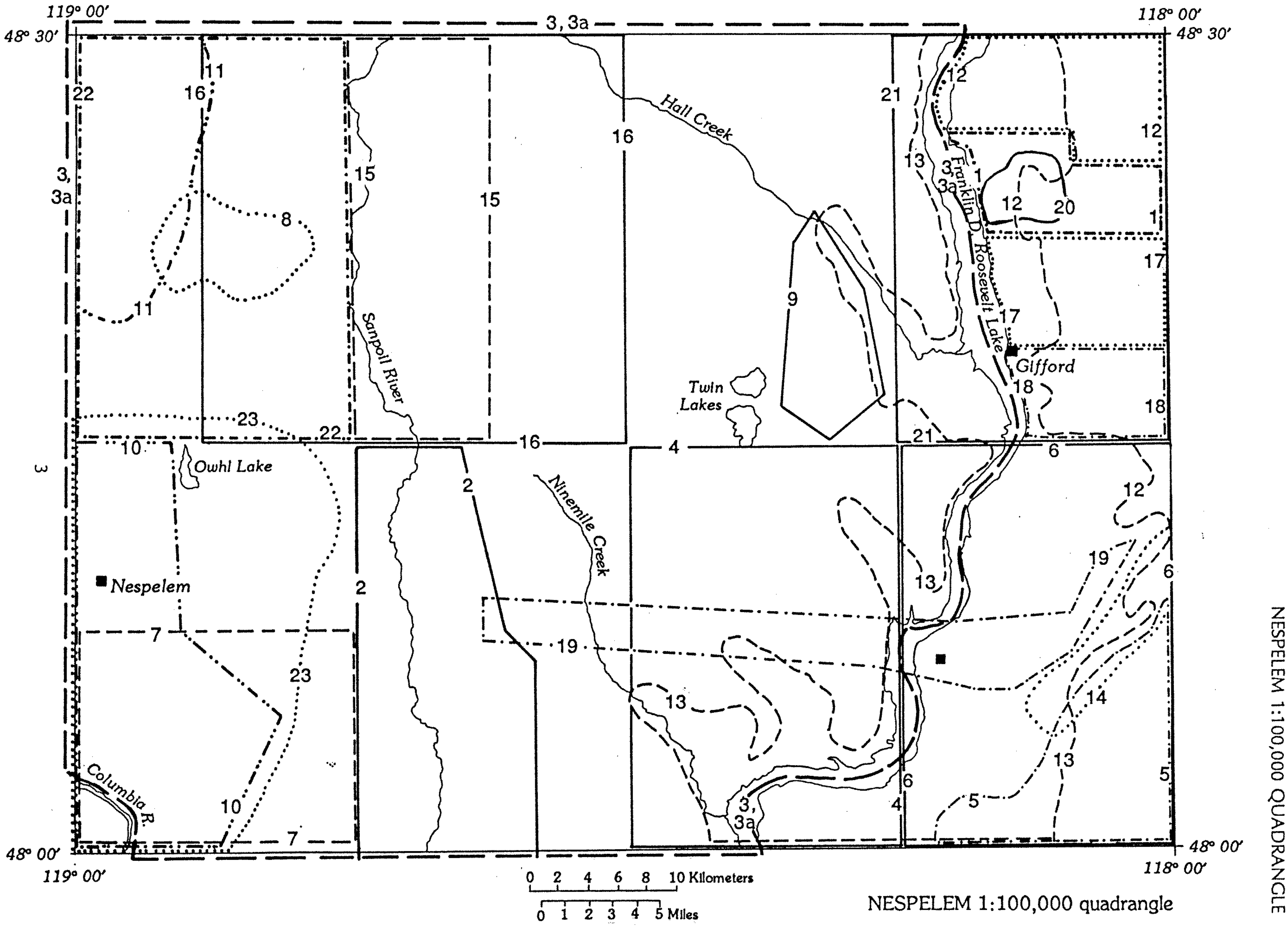


Figure 2. Sources of geologic mapping used to compile the Nespelem 1:100,000-scale quadrangle map.

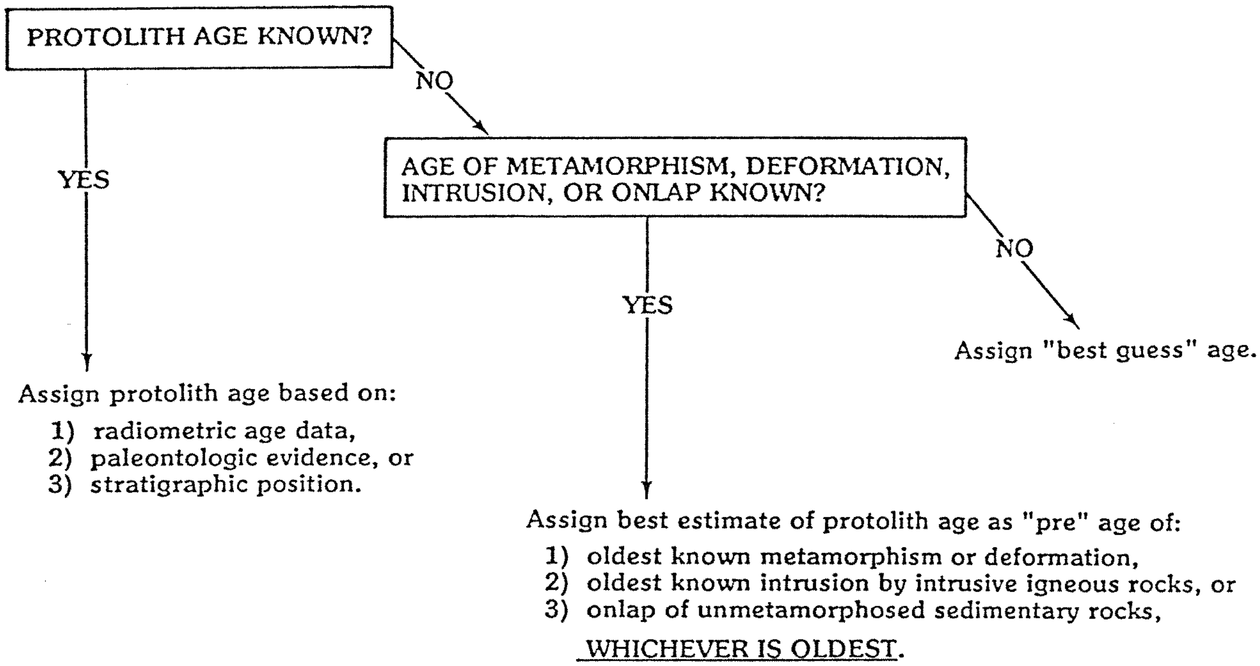


Figure 3. Flow chart for age assignment of geologic units, Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description includes information on how the age of the unit was determined.

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 quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 90-11, 58 p., 1 pl.

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

Stoffel, K. L.; McGroder, M. F., compilers, 1990, Geologic map of the Robinson Mtn. 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-5, 39 p., 1 pl.

Waggoner, S. Z., compiler, 1990, Geologic map of the Chewelah 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-14, 63 p., 1 pl.

Waggoner, S. Z., compiler, 1990, Geologic map of the Coulee Dam 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-15, 40 p., 1 pl.

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

Acknowledgments

G. M. Holder and R. W. Holder, both of Southern Georgia College, led a field trip in the Colville Indian Reservation and provided new information on plutonic rocks. B. F. Atwater, USGS, and C. D. Rinehart, USGS, shared new information and insights on the geology in the Colville Indian Reservation. J. R. Snook, Eastern Washington University, provided unpublished mapping of the Inchelium 15-minute quadrangle. M. T. Smith, University of Arizona, furnished an unpublished manuscript and shared her thoughts on the Covada Group and regional tectonics. E. P. Kiver, Eastern Washington University, offered additional information about and unpublished mapping of Quaternary units along the Columbia River. A. G. Harris, USGS, provided timely identification of conodonts. Claire Carter, USGS, supplied preprints of her graptolite data. J. T. Dutro Jr., USGS, led a field trip to fossil localities in the eastern part of the map area. S. Z. Waggoner and K. L. Stoffel, both of DGER, provided lively discussions and information about regional geology. The map and manuscript were reviewed by J. R. Logan, DGER, M. T. Smith, E. P. Kiver, J. R. Snook, A. G. Harris, C. D. Rinehart, and B. F. Atwater. Final copy was ably prepared by N. A. Eberle and J. R. Snider, both DGER.

GEOLOGIC SETTING

The Nespelem 1:100,000-scale quadrangle can be divided into four geologic blocks defined by major regional structures (Fig. 4). From west to east these are: (1) Paleozoic eugeoclinal metasedimentary rocks intruded by Eocene and older granitic rocks generally west of the Nespelem River fault; (2) Eocene volcanic and sedimentary rocks deposited in structurally controlled basins and associated Lower Tertiary hypabyssal and plutonic acidic and intermediate rocks and metamorphic rocks of the the Kettle metamorphic core complex west of the normal, low-angle Kettle River fault; (3) greenschist-facies, eugeoclinal, quartz- and chert-quartz-bearing metasedimentary and metavolcanic rocks of probable Ordovician to Carboniferous age west of the Huckleberry Range fault; and (4) greenschist-facies, Precambrian to Devonian miogeoclinal rocks. Eugeoclinal rocks in block 3 and probably in block 2 record deposition of continentally derived sediments in a submarine fan setting and intermittent periods of alkalic volcanism oceanward of the continental shelf. Lower Paleozoic miogeoclinal rocks in block 4 record deposition in a shelf to continental slope setting. The timing and the nature of the juxtaposition of the eugeoclinal and miogeoclinal rocks is uncertain, but the event is most probably pre-Cretaceous. Eocene extension resulted in the formation of northeast-trending, fault-bounded, volcanic and sedimentary rock-filled basins (Republic graben, Keller graben, and the Enterprise Valley), intrusion of dike swarms parallel to these structures, and the formation of metamorphic core complexes (Kettle gneiss dome) with nearly east-trending lineation. Metamorphic rocks in the Kettle metamorphic core complex are of unknown age and may in part have been metamorphosed during the Jurassic.

Explanation for Figure 4 (facing page)

Mv	Columbia River Basalt Group
Evs	Eocene volcanic and sedimentary rocks
lPze	Lower Paleozoic eugeoclinal rocks
uPzm	Upper Paleozoic miogeoclinal rocks
lPzm	Lower Paleozoic miogeoclinal rocks
P€	Windermere Group and Deer Trail Group
Eia	Herron Creek suite
	Eocene hypabyssal dike swarms
Eimd	Devils Elbow suite
EP$_{A}$ia	Keller Butte suite
TKia	Tertiary-Cretaceous (hornblende)-biotite granitic rocks
pTi	Pre-Tertiary hornblende-biotite intrusive rocks
ib	Basic intrusive rocks
pTm	High-grade metamorphic rocks

Thrust fault

Low-angle normal fault

Syncline

Anticline

Overturned anticline

Direction of lineation

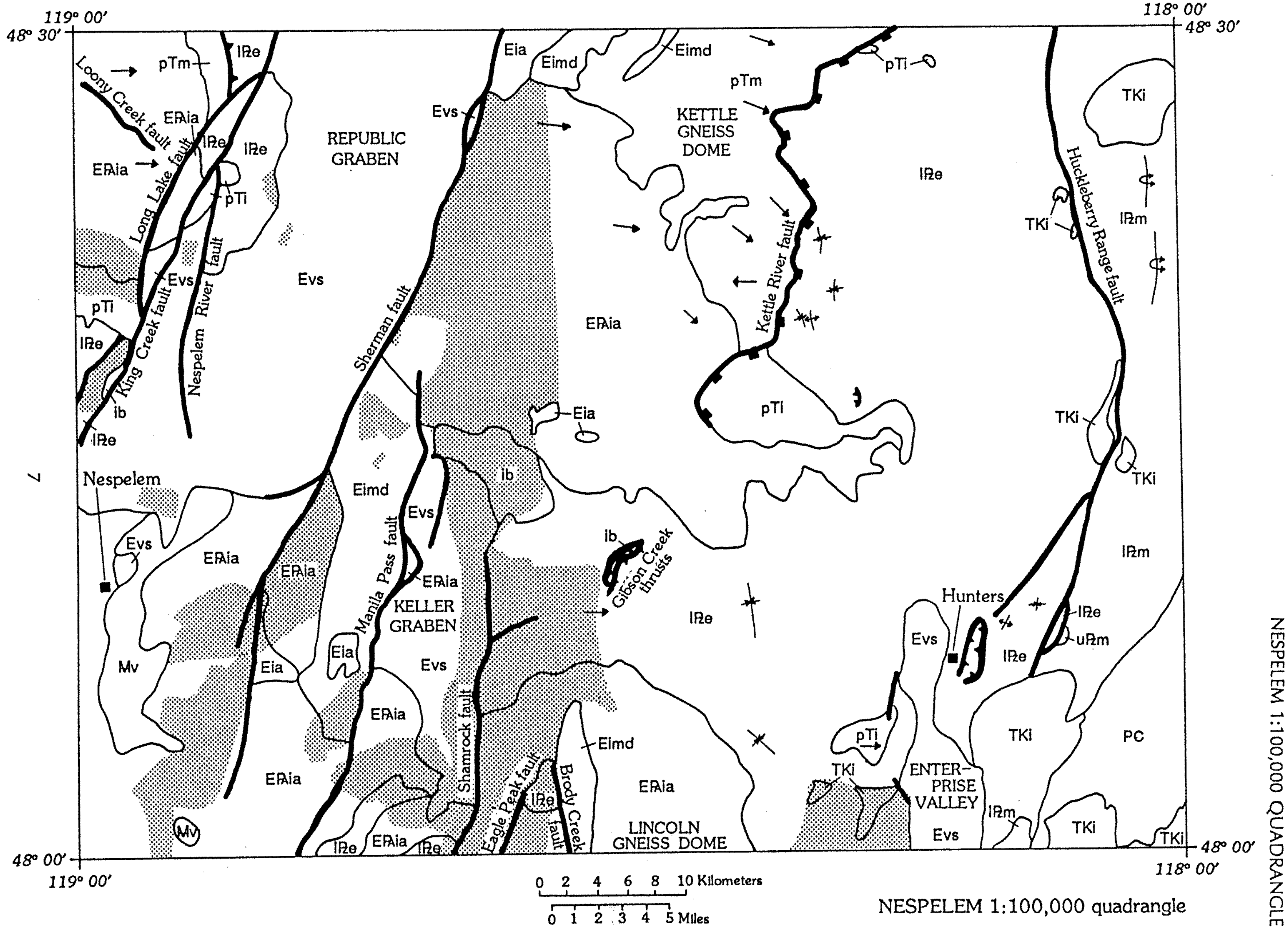


Figure 4. Generalized geologic map of the Nespelem 1:100,000-scale quadrangle.

DESCRIPTION OF MAP UNITS

Sedimentary and Volcanic Rocks and Deposits

Quaternary Sedimentary Deposits

Qs

Sediments, undivided (Holocene to Pleistocene)--Unconsolidated alluvial, glaciolacustrine, eolian, colluvial, and mass wasting deposits; generally shown where surficial geologic mapping is unavailable.

Nonglacial Deposits

Qa

Alluvium (Holocene to Pleistocene)--Silt, sand, gravel in streambeds and floodplains. The unit includes terraces and stratified sand and gravel in alluvial fans and locally includes eolian and lacustrine deposits.

Ql

Loess (Holocene to Pleistocene)--Poorly stratified, eolian silt and fine sand as much as 75 m thick and locally containing multiple petrocalcic horizons and tephra beds (Hanson, 1979). Regionally, the loess unconformably overlies Columbia River Basalt Group rocks and older bedrock. The unit has been eroded by floods from glacial Lake Missoula. Deposition may span the last 1 million years (McDonald and Busacca, 1989). Buried reversely magnetized paleosols interstratified with loess that are interbedded with flood gravels near Washtucna in the Connell 1:100,000-scale quadrangle indicate that some loess there was deposited prior to 780 ka. Also near Washtucna, a set C tephra from Mount St. Helens dated at >36 ka is interbedded with the loess (McDonald and Busacca, 1988).

Qls

Landslide deposits (Holocene to Pleistocene)--Mud flows, debris flows, and slump-earthflow landslides (Jones and others, 1961), including both ancient slides and those that have occurred subsequent to the filling of Franklin D. Roosevelt Lake. Most slides are in Quaternary sediments; many slides crown at the interface of bedrock with Quaternary deposits. Bedrock slides in the Columbia River Basalt Group are locally present where the basalt is interbedded with sediments (Jones and others, 1961).

Glacial Deposits

Most glacial deposits record late Wisconsin glacial activity. Pre-late Wisconsin (>35 ka; Richmond and Fullerton, 1986) glaciation is recorded by erratic cobbles above an elevation of 1,000 m along the Sanpoil River between Louie and Iron Creeks (Atwater, 1986). Older soils and tills are found at several localities, including the east and west flanks of Miller Mountain (Kiver and Stradling, 1986).

Qgd

Drift (Pleistocene)--Undivided glacial deposits; includes till, outwash, ice-contact stratified deposits, melt-water channel deposits, and terraces.

Qgl

Glaciolacustrine deposits (Pleistocene)--Bedded silt, varved silt and clay couplets, and fine lacustrine sand (Hanson, 1979). Most of this unit was deposited in glacial Lake Columbia that formed when the Okanogan lobe of the Cordilleran ice sheet dammed the Columbia River downstream from Grand Coulee in the Coulee Dam 1:100,000-scale quadrangle; the Sanpoil River was blocked by ice south of Keller (Kiver and Stradling, 1982; Atwater, 1986). The unit includes the Nespelem silt of Pardee (1918) along the Columbia River from approximately Hunters upstream to the border of the Colville Indian Reservation. Glaciolacustrine deposits interbedded with catastrophic flood deposits are shown as Qglf.

Atwater (1986) estimated that 2,000 to 3,000 varved silt and clay couplets were deposited in the area along Manila Creek. Varves are 0.5 cm to 4 cm thick and show little or no systematic upward decrease in grain size and varve thickness within individual varved intervals; however, varve thickness and grain size varies within the section. Lake water levels typically stood at an altitude of 500 m and reached 715 m. Water levels rose as high as 750 m during floods from glacial Lake Missoula (Atwater, 1986). Kiver and Stradling (1982) recognize six late Wisconsin terrace levels along the Columbia River north of the confluence with the Spokane River: 735 m, 610 to 671 m, 510 to 535 m, 475 to 490 m, 430 to 455 m, and 405 to 420 m. Wood from a varved couplet at an elevation of 449 m along Manila Creek returned a radiocarbon age of 14,490 ± 290 yr B.P. The age of the wood, coupled with the number of varves at the Manila Creek section, led Atwater (1986) to estimate that Lake Columbia existed for 2,000 to 3,000 years, from 16,000 to 12,400 yr B.P.

Qglf

Glaciolacustrine and catastrophic flood deposits, undivided (Pleistocene; Wisconsin)--Glaciolacustrine deposits (Qgl) interbedded with flood deposits from glacial Lake Missoula (Atwater, 1986) and/or possibly from local ice dam failure in the Columbia River valley (Kiver and Stradling, 1986). In the valley of Manila Creek an estimated 2,000 to 3,000 varves are interbedded with no fewer than 89 beds, each of which record a Lake Missoula outburst flood (Atwater, 1986). Flood sediments are present in beds 1 m thick or greater and decrease in thickness and grain size upsection. Upward-fining sequences of fine to medium sand with silt or mud tops are cut into varved lake-bed sediments. This unit includes the Nespelem silt of Pardee (1918) along Franklin D. Roosevelt Lake from Hunters to Grand Coulee Dam and in the valley of the Sanpoil River. Lake Columbia likely reached an altitude of 750 m during outbursts of glacial Lake Missoula as evidenced by erratics that include boulders of granitic and Belt Supergroup rocks in the lower Sanpoil Valley (Atwater, 1986). In most places the unit is unconformably overlain by gravelly outwash that is not shown separately on the map (B. F. Atwater, USGS, written commun., 1990).

Qgo

Outwash (Pleistocene)--Well sorted, crudely stratified layers of sand and gravel. The unit locally includes moraine and kame terraces along Ninemile and Wilmont Creeks, on Miller Mountain, and on the West Fork of the Sanpoil River (Kiver and Stradling, 1986)

Qgt

Till (Pleistocene; late Wisconsin)--Partly sorted and crudely stratified till that is common along Franklin D. Roosevelt Lake and more than 100 m above the lake. Unsorted, nonbedded till is more common away from the area once covered by glacial Lake Columbia (Kiver and Stradling, 1986).

Qgto

Older till (Pleistocene; pre-late Wisconsin)--Characterized by weathered soils that exhibit a yellowish brown to dark yellowish brown B horizon that is weakly to moderately argillic and displays some clay skins (Kiver and Stradling, 1986; Kiver and others, 1989). The unit includes possible older tills on the east flank of Miller Mountain that are characterized by thick, oxidized argillic soils that enclose highly weathered clasts. The B horizon there is reddish brown to dark reddish brown; granitic clasts are weathered to grus (Kiver and Stradling, 1986; Kiver and others, 1989).

Tertiary Sedimentary and Volcanic Rocks

Columbia River Basalt Group

Mv_{wp}

Wanapum Basalt, Priest Rapids Member (middle Miocene)--Fine- to coarse-grained aphyric basalt flows of reversed magnetic polarity. The unit locally contains phenocrysts of plagioclase and olivine. It is of the Rosalia chemical type and has higher iron and titanium and lower magnesium contents than other flows of the Wanapum Basalt (Swanson and others, 1979a). The unit is present in the southwest corner of the map area.

Mv_{gN2}

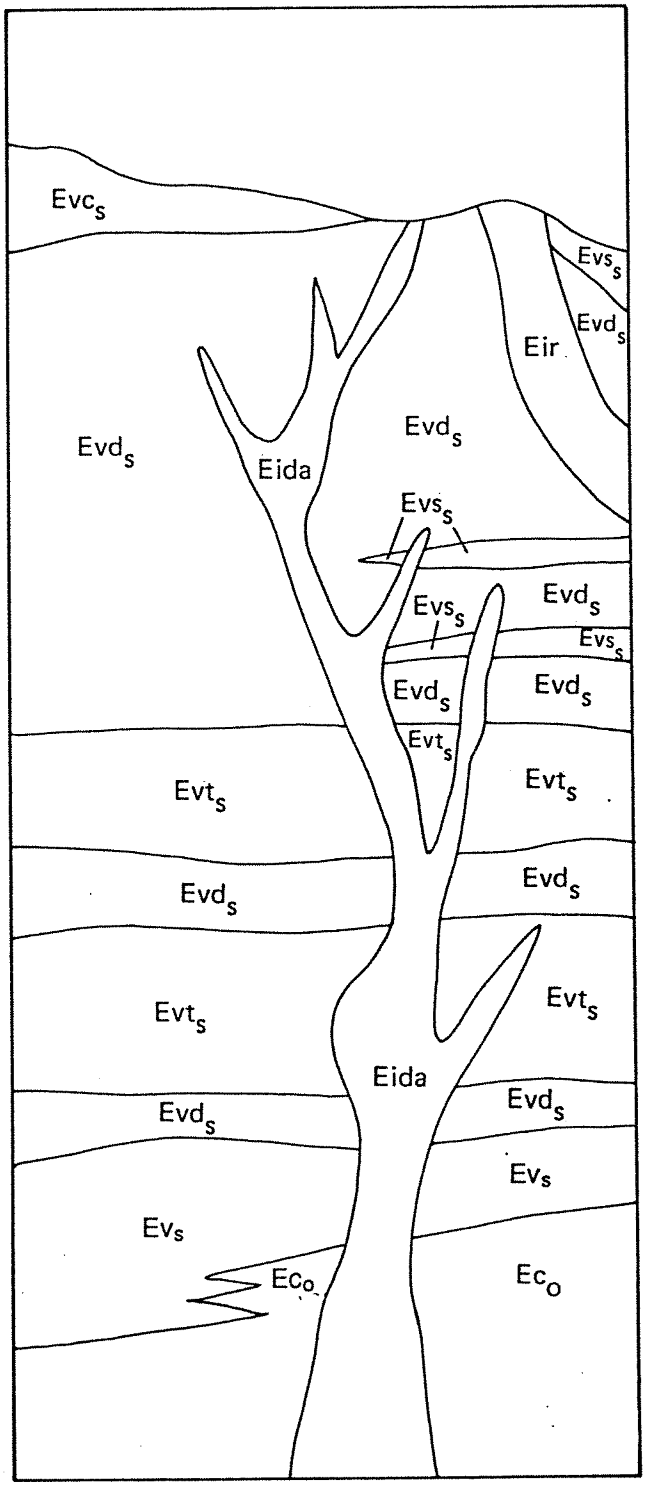
Grande Ronde Basalt, magnetostratigraphic unit N_2 (middle Miocene)--Upper flows of the Grande Ronde Basalt; aphyric to sparsely phyric basalt with minor small plagioclase laths and of normal magnetic polarity. The unit unconformably overlies a variety of older rocks. Flows are 1 to 50 m thick, but generally range from 15 to 25 m thick and are commonly pillowed (Swanson and others, 1979b).

Eocene Volcanic and Sedimentary Rocks

Eocene dacite and andesite flows and sedimentary rocks in the Nespelem 1:100,000-scale quadrangle are present in the southern part of the Republic graben, in the Keller graben, and in the Enterprise Valley (Fig. 4). Similar rocks in the Republic graben on the Republic 1:100,000-scale quadrangle have been subdivided by Muessig (1967) into three units, from youngest to oldest: the Klondike Mountain Formation, the Sanpoil Volcanics, and the O'Brien Creek Formation (Fig. 5). Eocene volcanic and sedimentary rocks in the Enterprise Valley were named the Gerome andesite by Weaver (1920) and have been correlated by Pearson and Obradovich (1977) with the units named by Muessig (1967) in the Republic graben.

The Sanpoil Volcanics are believed to be coeval, and possibly comagmatic with intrusive rocks of the Devils Elbow and Herron Creek suites. The Devils Elbow suite and the medium-grained quartz monzonite intrusions of the Herron Creek suite, which are chemically similar to the Sanpoil Volcanics, have been observed to grade up into dacite hypabyssal dikes (Scatter Creek Rhyodacite of Muessig, 1967), which are feeder dikes for flows of the Sanpoil Volcanics (Moye, 1984; Holder and Holder, 1988; Holder and others, 1989).

Deposition of these rocks was contemporaneous with Eocene extension related to the formation of the grabens (Holder and others, 1989). Holder and others (1989) suggest that regional Tertiary extension was accommodated by simultaneous regional ductile stretching, resulting in the formation of the metamorphic core complexes (Kettle metamorphic core complex, Okanogan dome) with nearly east-trending lineation and brittle deformation that resulted in the formation of the grabens and dike swarms of Eocene subvolcanic rocks which, in turn, are elongate perpendicular to the direction of regional stretching (Figs. 4 and 6). Deposition of the Klondike Mountain Formation, which is not exposed in the Nespelem quadrangle, is thought to postdate regional mylonitization but predate the final stages of graben formation (Holder and others, 1989).



EXPLANATION

Eir	Intrusive rhyolite near West Fork
	Sanpoil Volcanics
Evc$_s$	Volcanic breccia
Eida	Hypabyssal dacite dikes
Evs$_s$	Sedimentary rocks
Evd$_s$	Dacite flows
Evt$_s$	Pyroclastic rocks
Ev$_s$	Rhyodacite of Cub Hill
Ec$_o$	O'Brien Creek Formation

Figure 5. Stratigraphy of the Eocene volcanic and sedimentary rocks in the Nespelem 1:100,000-scale quadrangle. Modified from figure 6 of Moye (1984).

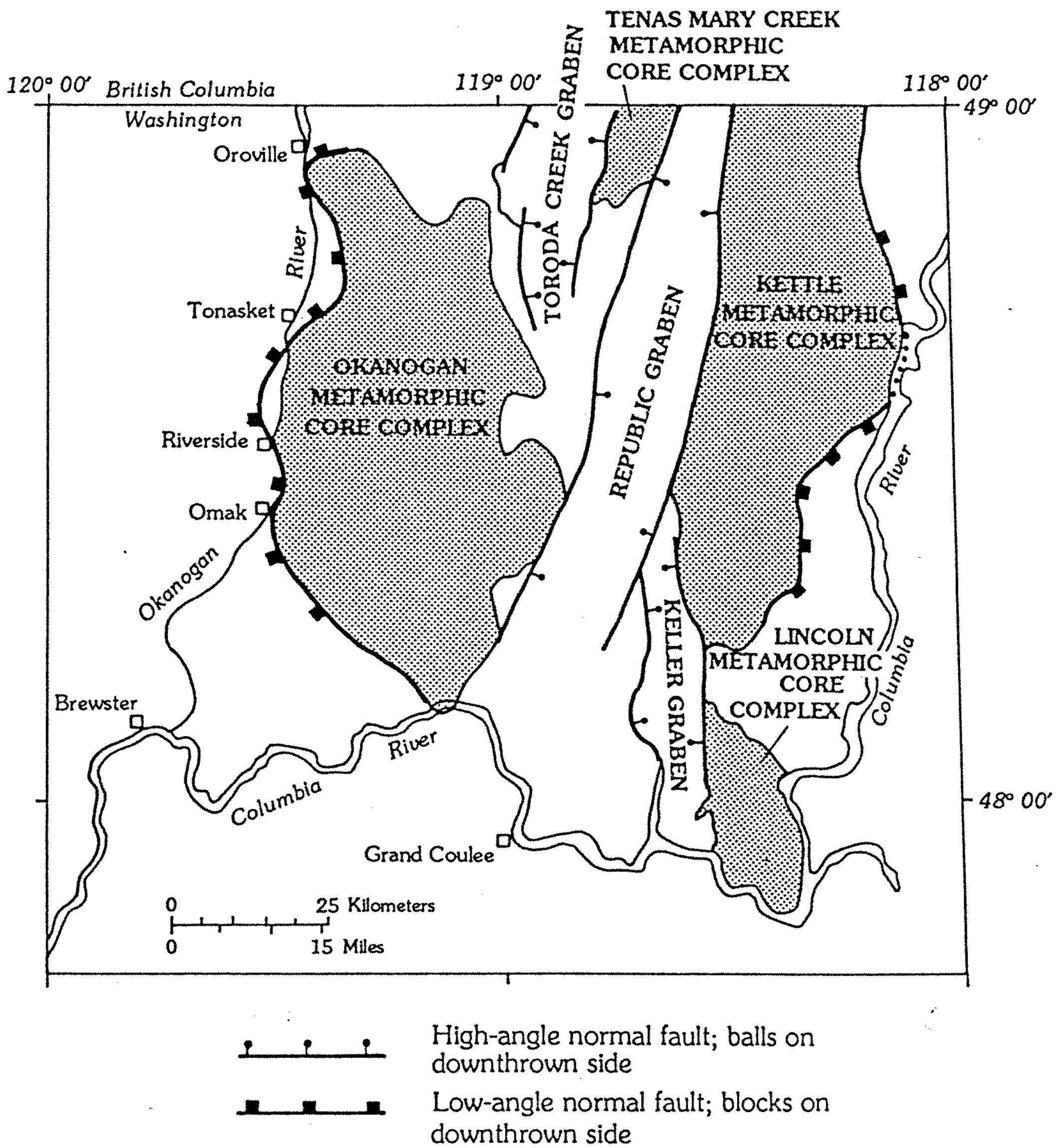


Figure 6. Metamorphic core complexes in the Okanogan highlands of northeastern Washington (after Fox and Rinehart, 1988).

Evc_s, Evd_s, Evs_s, Evt_s, Ev_s

Sanpoil Volcanics (Eocene)--Phyric dacite to andesite flows (Fig. 7) with subordinate pyroclastic and epiclastic rocks. As mapped, the unit locally includes some hypabyssal intrusive rocks. Flows contain 20 to 50 percent phenocrysts, which are chiefly plagioclase, hornblende, biotite, augite, and/or pigeonite; quartz is generally absent. The aphanitic, lithoidal groundmass is composed of quartz and alkali feldspar (Moye, 1984). The Sanpoil Volcanics are estimated to be 1,200 m thick to the north in the Republic area (Muessig, 1967), more than 700 m in the northern part of the Nespelem quadrangle, and 1,500 m in the southern part of this quadrangle (Moye, 1984).

Distinctive variations are evident in the eruptive sequence from south to north in the southern part of the Republic graben. Lava flows and volcanic flow breccia predominate in the central and northern part of the Republic graben. Lava flows intercalated with ash-flow tuff make up a considerable part of the sequence south of Twentythree Mile Creek. Ash-flow tuff near the base of the sequence indicates that early volcanism was explosive; it was followed by intermediate lava flows and waning explosive activity. Sedimentary rocks are most abundant near the margins of grabens (Moye, 1984).

K-Ar ages from biotite are: 48.5 ± 0.3 Ma from flows in the upper part of the Sanpoil unit from along the Sanpoil River near Seventeenmile Creek; 50.3 ± 0.4 Ma from a vitrophyric flow north of Bridge Creek in the Keller graben (Atwater and Rinehart, 1984); and 48.9 ± 1.2 Ma from a hornblende-biotite-bearing flow in the southwestern part of the rhyodacite of Cub Hill (Atwater and Rinehart, 1984).

The Sanpoil Volcanics conformably and unconformably overlie the O'Brien Creek Formation (Fig. 5); the contact is locally gradational. The Sanpoil Volcanics are possibly coeval and comagmatic with intrusive rocks of the Devils Elbow and Herron Creek suites. Holder and others (1989) suggest that deposition of the Sanpoil Volcanics was contemporaneous with intrusion of the Devils Elbow suite, core complex emplacement, and graben faulting. Extrusion of the upper flows of the Sanpoil Volcanics, intrusion of the Herron Creek suite, and epiclastic sedimentation of the Sanpoil Volcanics postdate regional mylonitization but predate cessation of graben faulting (Holder and others, 1989).

The Sanpoil Volcanics are subdivided in the southeastern part of the Republic graben and in the Keller graben as follows:

Evc_s

Volcanic breccia--Monolithic, weakly stratified, moderately sorted agglomerates that contain subangular to subrounded clasts of biotite- and pyroxene-bearing dacite in a matrix of finely broken material of the same composition. The unit is spatially associated with, and dips gently (<10° northwest) away from the intrusive rhyolite near the West Fork Sanpoil River. The breccia may define a volcanic vent (Moye, 1984). The unit is present in the northern part of the Sanpoil River valley (secs. 25, 36; T. 35 N., R. 32 E.; Moye, 1984); it is also present elsewhere but is not mapped west of the Sanpoil River.

Evd_s

Dacite flow rock--Brown and gray, phyric dacite and andesite flows containing 20 to 50 percent phenocrysts of hornblende, augite, biotite, pigeonite, and/or hypersthene in medium- to dark-gray, directionless groundmass that is comprised of intergrown, microcrystalline quartz and K-feldspar. Phenocrysts of quartz and K-feldspar are rare (Atwater and Rinehart, 1984; Moye, 1984), and the rock contains less than 3 percent fine-grained plagioclase. Subhedral to euhedral, unzoned plagioclase (An_{52-58}) comprises 3 to 38 percent of the phenocrysts. Hornblende and augite constitute as much as 16 and 12 percent of the phenocrysts, respectively; biotite is subordinate to other mafic minerals, and olivine is locally present. Accessory minerals include apatite, zircon, titanite, and magnetite. The flows display various amounts of alteration, most of which is considered to be deuteric (Moye, 1984).

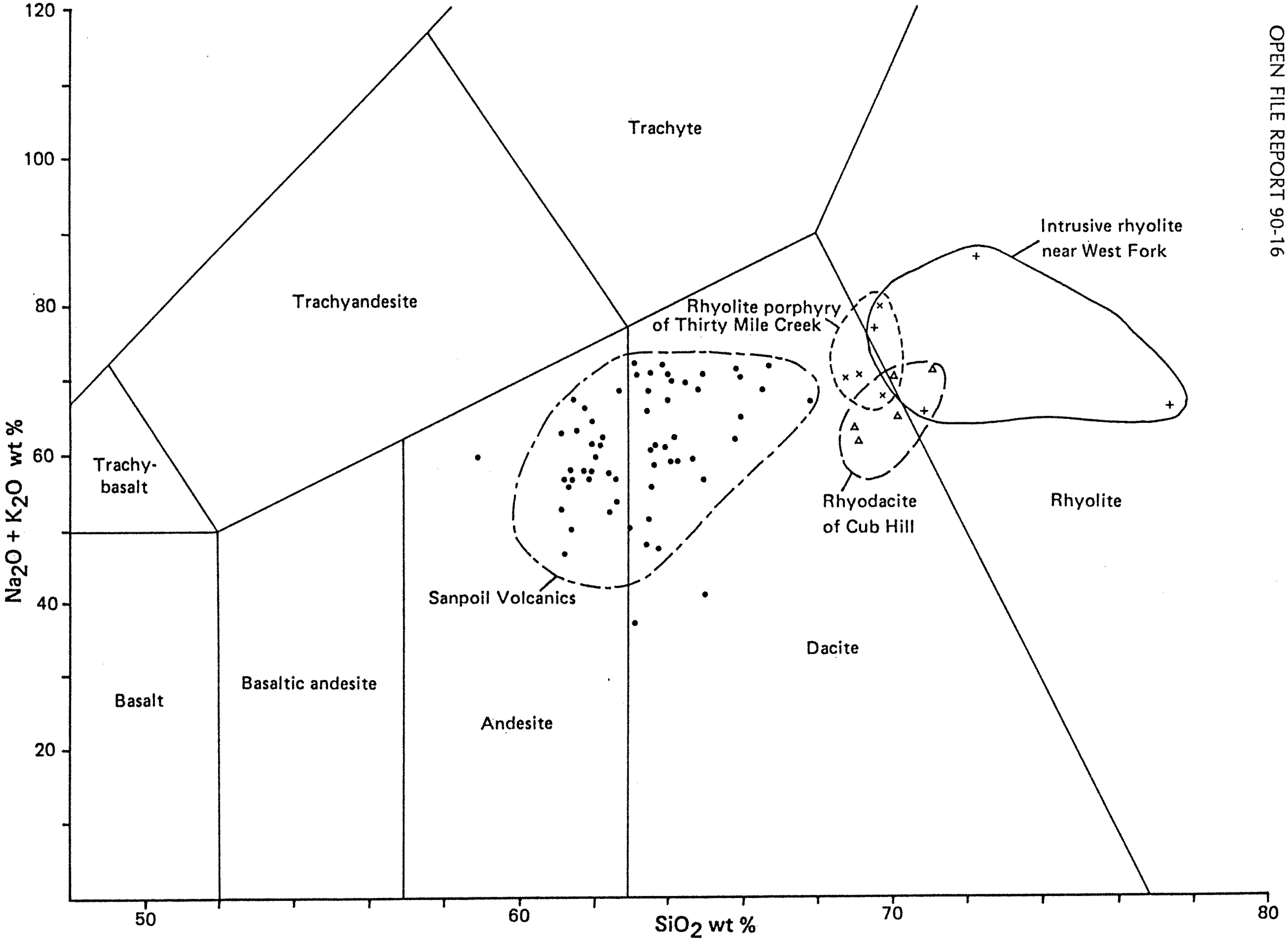


Figure 7. Geochemical data from Moye (1984) for Eocene rocks in the southern Republic and Keller grabens plotted on a TAS diagram. The rhyolite porphyry of Thirty Mile Creek is included with the biotite-bearing phase of the hypabyssal dacite dikes (Eida)

Individual flows generally range from less than 6 m to more than 70 m thick; they are interbedded with sedimentary and pyroclastic rocks throughout the section. Along the West Fork Sanpoil River, a 400-m-thick pile of coalescing flow lobes appears to have been extruded over a short time; it does not contain significant breaks (Moye, 1984). The flows may have been ponded over a source area (Moye, 1987). North of the West Fork, flows have distinct tops and bottoms and are 20 m to 70 m thick; autoclastic breccia zones are as much as 10 m thick at the top or base of flows. East of the Sanpoil River, lava flows appear to be discontinuous, coalescing, and generally thinner than 30 m (Moye, 1984).

In the Enterprise Valley the flow unit of the Sanpoil Volcanics is estimated to be more than 457 m thick; individual flows range from 23 m to 30 m thick (Becraft and Weis, 1963). Flows are intercalated with epiclastic and volcaniclastic rock, and tuff.

Evs_s

Volcanic and sedimentary rocks--Thin, discontinuous tuffaceous siltstone to coarse conglomerate intercalated with volcanic flows (Evd_s). Tuffaceous rock contains quartz and plagioclase, lesser amounts of hornblende and pyroxene, and minor biotite. Lithic fragments include pre-Tertiary igneous and metamorphic rock and subordinate Eocene volcanic rock. Finely laminated siltstone of the unit is probably lacustrine in origin. Poorly preserved leaf and stem fragments are locally abundant. The paucity of volcanic rocks suggests that the highland source area had only thin cover of volcanic rocks (Moye, 1984).

Evt_s

Pyroclastic rocks--Ash-flow tuff and tuff breccia intercalated with flows; mapped only in the Republic graben east of the Sanpoil River and in the Keller graben. The unit includes basal vitric-crystal tuff that grades upward into lapilli tuff in units 8 to 35 m thick. Vitric-crystal tuff contains 40 to 75 percent broken phenocrysts of plagioclase, hornblende, clinopyroxene, and biotite and minor quartz and sanidine in a groundmass of microcrystalline quartz and K-feldspar (devitrified glass). Fragments of Eocene volcanic rock and metamorphic rock are also included (Moye, 1984).

Ev_s

Rhyodacite of Cub Hill (Moye, 1984) (Eocene)--Light-colored, crystal-vitric tuff, lapilli tuff, pumice-bearing lithic tuff, and light-colored, massive, porphyritic hornblende-biotite- and biotite-bearing flows and hypabyssal dikes. This unit overlies and is interbedded with sedimentary rocks mapped as O'Brien Creek Formation. The unit was mapped as Sanpoil Volcanics by Staatz (1964) and Atwater and Rinehart (1984); Pearson and Obradovich (1977) and Moye (1984; 1987) suggested it be included with the O'Brien Creek Formation (Fig. 7). Samples analyzed by Moye (1984) plot in the dacite field along the border of the rhyolite field on a TAS diagram and are chemically distinct from the plot of samples from the Sanpoil Volcanics (Fig. 7). This unit may represent a volcanic unit separate from the Sanpoil Volcanics or more felsic flows near the base of the Sanpoil Volcanics. As identified by Staatz (1964, p. F39), tuffaceous rocks predominate between the South and North Forks of Nanamkin Creek, on the main ridge east of the Nespelem River and south of Kinkaid Creek. Light-colored hornblende-biotite-plagioclase porphyritic flows dominate the unit to the south and west of that area. Flows and tuffs have been propylitic altered north of the confluence of Stepstone Creek and the Nespelem River; biotite appears to be fresh and epidote is absent to the south and west.

The rhyodacite of Cub Hill as described by Moye (1984) contains light-green to white lapilli tuff that contains 10 to 60 percent subrounded pumice clasts and minor nonvolcanic fragments in a groundmass of microcrystalline quartz, K-feldspar, plagioclase, and minor hornblende and biotite. Light-green to white crystalline tuff contains broken phenocrysts of 30 to 50 percent plagioclase, 5 to 9 percent quartz, biotite, and orthoclase in a groundmass of microcrystalline K-feldspar, quartz, and finely comminuted glass. The tuff in this unit is distinguished from other pyroclastic deposits in the Sanpoil Volcanics by its general lack of hornblende and pyroxene. Thin crystalline tuff containing compacted pumice fragments is interbedded with gently dipping tuffaceous conglomerates of the O'Brien Creek Formation along the Central Peak road (Moye, 1984). Flows include massive, light-green to pinkish-gray, porphyritic dacite with euhedral to subhederal plagioclase (An_{44}), 3 to 8 percent quartz, biotite, and fine, euhedral hornblende.

Ec$_o$

O'Brien Creek Formation (Eocene)--Light-colored tuffaceous sandstone, tuff, conglomerate, and minor lava flows found at the base of the Eocene volcanic sequence. The unit is mostly thick beds of greenish-white, coarse-grained, water-laid crystal tuff that contains characteristic chips of dark-colored argillite and phyllite lying parallel to bedding; minor quartzite and glassy volcanic fragments are also present. Mineral grains are primarily feldspar, embayed quartz, and biotite; hornblende is absent. Air-laid tuff is generally welded and contains fragments of older rocks. Crystal fragments make up 20 to 65 percent of the tuff and include hornblende, biotite, quartz, orthoclase, magnetite, and titanite. Angular to rounded, poorly sorted conglomerate is present as local interbeds in the upper and the basal parts of the formation. Boulders as large as 2 m in diameter are found in the basal part of the unit; well-rounded boulders of granite, schist, phyllite, argillite, volcanic, and hypabyssal rocks are present in the upper part (Moye, 1984). The formation is estimated to be 900 m thick between Bridge and Louie Creeks (Atwater and Rinehart, 1984). In the Keller graben, the O'Brien Creek Formation includes light-colored flow rock and tuff that lie unconformably on the erosional surface of granitic rocks (Atwater and Rinehart, 1984). The unit unconformably overlies pre-Tertiary rocks; the contact with the Sanpoil Volcanics is probably not everywhere at the same stratigraphic horizon (Moye,1984).

Pearson and Obradovich (1977) correlate the lower conglomerate in the Enterprise valley with the O'Brien Creek Formation. Fossils in the unit there include: Metasequoia occidentalis (Newberry) Chaney, ?Sequoia affinis Lesquereux, and pollen identified as Betula, Alnus, cf. Picea, cf. Engelhardtia, cf. Pterocarya, cf. Ulmaceae, cf. Zelkova, and cf. Sequoia (Becraft and Weis, 1963).

Paleozoic and Older Metasedimentary and Metavolcanic Rocks

Rocks Generally West of the Manila Pass Fault

Low-grade metasedimentary rocks are present west of the Manila Pass fault. While some of these rocks resemble rocks of the Covada Group, which is well exposed to the east in the Nespelem quadrangle, other rocks may be similar to the Permian Anarchist Group that is mapped to the north in the Republic 1:100,000-scale quadrangle. Rocks west of the Long Lake fault, while similar to other metasedimentary rocks exposed west of the Sherman fault, are fault-bounded and intruded by serpentinites of unknown age and may correlate with metasedimentary rocks to the north on the Republic 1:100,000-scale quadrangle. Although some fossils have been collected from rocks west of the Manila Pass fault, none has provided a specific age determination.

Pmm

Metasedimentary rocks (Permian ?)-Includes highly folded, fine-grained, silvery-gray to dark-gray phyllite mapped by Staatz (1964) north of the West Fork of the Sanpoil River. The phyllite is composed of quartz, sericite, and chlorite with accessory biotite, limonite, graphite, zoisite, tourmaline, titanite, and psuedochiastolite. The unit locally contains beds of quartzite, wacke, and limestone.

Pzw

Wacke and quartzite (Paleozoic)--Wacke and quartzite with weak foliation in fault contact with other metasedimentary rocks. The wacke is generally present north of Strawberry Creek and on the east side of Gold Creek. The wacke contains crystal and rock fragments ranging from 0.02 to 5.0 mm in diameter that make up 40 to 70 percent of the wacke; the matrix is very fine grained quartz, chlorite, sericite, and minor feldspar. Rock fragments rarely exceed 5 percent of the total rock and consist of clasts of quartzite, chert, and greenstone; angular to subrounded crystal fragments are chiefly quartz. Minor plagioclase is generally present; orthoclase or microcline locally make up as much as 25 percent of the fragments. Calcite, zircon, magnetite, tourmaline, biotite, and hornblende are also locally present, but none exceeds 1 percent of the rock. The upper part of the unit contains considerable interbedded phyllite similar to that in the argillite (Pzar) unit. Thin beds of calcareous tuff and small limestone lenses are locally included (Staatz, 1964).

Thin- to thick-bedded, fine- to medium-grained, white, light- to medium-gray to light-brown quartzite is present along North Star Creek. Grains are commonly recrystallized; the unit contains minor sericite and, locally, biotite or chlorite. Irregular grains of calcite are present. The quartzite also contains less than 1 percent each of zircon, magnetite, hematite, and titanite. Locally the quartzite is interbedded with phyllite and quartz-mica schist. Small bodies of tremolite-bearing quartzite near Little Owhi Lake closely resemble quartzites near North Star Creek; these quartzites were probably originally carbonate-bearing (Staatz, 1964).

The wacke and quartzite unit is correlated by Staatz (1964) and M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) with the rocks of the Covada Group. Atwater and Rinehart (1984) report that a sharpstone conglomerate, which is a common sedimentary unit in the Permian Anarchist Group (which is present in the Republic 1:100,000-scale quadrangle), is associated with quartzites at one locality west of the Long Lake fault.

Pzcb

Carbonate rock (Paleozoic)--Carbonate pods and lenses interbedded with argillite and wacke. In the western part of the map area, along North Star Creek, a prominent 137-m-thick limestone lens is present 152 m above the base of a unit of black argillite. The limestone is black to dark gray and finely laminated and contains 1 to 20 percent quartz grains and local tremolite (Staatz, 1964). This limestone appears to be a turbidite and contains reworked blocks of medium-gray, crinoid-bearing limestone, which may be olistoliths. Poorly preserved fragments of pelecypods, gastropods, and echinoderms were identified from a limestone lens in sec. 7, T. 33 N., R. 31 E. (Staatz, 1964). Pardee (1918, p. 26) reported coral fragments from a limestone pod on Lime Creek in a fault-bounded sliver along the Manila Pass fault. The carbonate rock is brecciated where it is adjacent to the Long Lake fault.

Pzar

Argillite (Paleozoic)--Black, well-laminated, very fine grained siltite and argillite intercalated with dark-red, hematitic, massive siltite and minor limestone on either side of the Long Lake fault. This rock contains quartz, chlorite, sericite, and carbonaceous material on the east side of the Long Lake fault. West of the fault, the rock is very fine grained black siltite and siliceous siltite with minor fine-grained, brownish quartzite. It contains 0.005-m grains of quartz, sericite, and chlorite; carbonaceous material may comprise as much as 35 percent of the rock. The unit west of the fault is at least 701 m thick (Staatz, 1964). Staatz (1964) and M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) correlate this unit with the Covada Group.

Pzmm

Metasedimentary rocks, undivided (Paleozoic)--Wacke, quartzite, argillite, and carbonate rocks west of the Manila Pass fault outside of the Bald Knob 15-minute quadrangle, which is in the northwest corner of the map area.

Rocks West of the Huckleberry Range Fault

Eugeosynclinal rocks west of the Huckleberry Range fault consist of chert-quartz and quartz-feldspar subarkosic to arkosic wacke, quartz arenite, basaltic greenstone, carbonate rock, argillite, and conglomerate. Most of these rocks have been mapped as the Covada Group (Pardee, 1918; Campbell and Raup, 1964; Snook and others, 1981). M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) suggest that chert-quartz-bearing metasedimentary rocks be excluded from the Covada Group on the basis of lithology and presumed age differences. Smith and Gehrels call the chert-quartz-bearing unit the Bradeen assemblage and suggest that it is younger than Covada Group rocks, the upper part of which contains Early Ordovician macro- and microfossils on Butcher Hill.

Smith and Gehrels also suggest that the sequence of the Covada Group and the younger Bradeen assemblage, which are in depositional contact, are younger to the east on the basis of mapping and examination of facing indicators. The Bradeen assemblage is in fault contact with miogeoclinal rocks to the east. Snook and others (1981) suggest the structure that juxtaposes the eugeoclinal and miogeoclinal rocks is a thrust fault of post-Middle Ordovician and pre-intrusive rock age. Smith (1989) proposes that it is a high-angle, anastomosing shear zone that has possible strike-slip displacement.

Rocks near Bradeen Hill

COcg

Chert-pebble conglomerate (Carboniferous-Ordovician)--Matrix-supported conglomerate containing subangular and subrounded elongate pebbles of siliceous argillite and white to brown chert in a dark-gray to dark-green siliceous matrix. The unit also contains subordinate clasts of vein quartz, quartzo-feldspathic quartzite, quartz arenite, argillite, and rare volcanic rocks. The lithic arenite matrix makes up 15 to 90 percent of rock and contains fine-grained quartz and biotite. The unit includes a breccia with flat or elongate 5- to 10-cm-long limestone clasts floating in a phyllitic or argillaceous matrix; the breccia is well preserved on Butcher Mountain. M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) correlate the unit with the chert-quartz-bearing metasedimentary rocks (COmm, COcg) in Echo Valley in the Colville 1:100,000-scale quadrangle.

COmm

Chert-quartz-bearing metasedimentary rocks (Carboniferous-Ordovician)--Fine- to medium-grained, thin- to medium-bedded, well-sorted, subangular to well-rounded, chert-quartz-bearing arenite, argillite, and slate.

COw

Chert-quartz-bearing quartzite and wacke (Carboniferous-Ordovician)--Chert-quartz arenite that contains 45-80 percent monocrystalline quartz, 18-54 percent lithic clasts of siliceous argillite and chert, local clasts of volcanic origin, and 2 percent feldspar. The unit also contains several thick beds of coarse-grained, medium- to dark-gray, biomodal quartz arenite in which about 99.98 percent of the clasts are composed of well-rounded quartz grains and rare tourmaline and zircon; black opaque material comprises 5 percent of the matrix (M. T. Smith and G. E. Gehrels, Univ. of Arizona, written commun., 1990).

Medium- to dark-gray and black, fine-grained, medium- to thick-bedded, well-jointed quartzite interbedded with dark-gray argillite is exposed west of the Columbia River. The 200- to 300-m-thick unit contains rounded fine quartz grains in a very fine grained quartz matrix. Abundant black organic material and minor opaque minerals give the rock its black color; locally it contains volcanic detritus and minor subangular fragments. The quartzite conformably overlies greenstone with a sharp contact and is conformably overlain with a sharp contact by wacke in the Twin Lakes area (Fullmer, 1986).

COar

Siliceous argillite, phyllite, and chert (Carboniferous-Ordovician)--Fine- to medium-bedded, gray to black chert and siliceous argillite, slate, and phyllite composed of strained quartz, white mica, and black opaque material. The unit includes lenses of pillowed, basaltic greenstone (COmv) where exposures are too small to show as separate bodies at this map scale. Radiolarian ghosts are common in the more siliceous and better preserved layers. The unit is more than 100 m thick (M. T. Smith and G. E. Gehrels, Univ. of Arizona, written commun., 1990). The unit contains lenses of wacke in northeastern part of the map area (Janzen, 1981) and along the Columbia River, and near Twin Lakes the unit is distinguished by the lack of interbedded wacke, but it does contain interbeds of black quartzite (Smith, 1989; Fullmer, 1986). Hornfels and spotted phyllite are present where the rocks are metamorphosed near Twin Lakes (Fullmer, 1986). At the contact with the porphyritic granodiorite of Manila Creek (EPA ia$_m$), the rock is silver-gray semischist, biotite schist and tourmaline-bearing schist (Smith, 1989). The unit is also hornfelsed on the east end of Old Copper Hill.

On the east side of the Columbia River, this unit includes dark-gray, brownish-weathering slate and phyllite and distinctive grey-blue-weathering slate and siltite that have pronounced flaggy cleavage and interbedded dark-gray to black, thin- to medium-bedded, thinly laminated to massive, recrystallized chert to very fine grained quartzite (Smith, 1989).

COcb

Carbonate rock (Carboniferous-Ordovician?)--Interbedded light- to dark-gray, thin- to medium-bedded, medium to thick graded laminated limestone, argillaceous limestone, phyllite, and chert; present north of Hunters Creek. The unit is believed to be fault-bounded and exhibits strong cleavage.

A Middle Cambrian to Early Ordovician (no younger than lower Fauna C) age was assigned by A. G. Harris and J. E. Repetski (USGS, written commun., 1986) based on the occurrence of the conodont Furnishina sp. indet. from the outcrop on the Springdale-Hunters Road (SE1/4SE1/4NW1/4 sec. 2, T. 30 N., R. 37 E.). The conodonts have a CAI of 5, indicating that the host rock reached at least 300 deg. C. On the basis of the fossil data, the rock could be slightly older than suggested by this report; however, the conodont samples are within a sequence of proximal turbidites, and therefore the conodonts may not be indigenous to the rock.

COmv

Greenstone (Carboniferous-Ordovician)--Aphanitic, pillowed, basaltic greenstone that forms lenses as much as 20 m thick in the southern part of the rocks near Bradeen Hill on the east side of the Columbia River. The lenses thicken along strike to the north, where they comprise as much as 30 percent of the section (M. T. Smith and G. E. Gehrels, Univ. of Arizona, written commun., 1990). These rocks are similar in composition to greenstones in the Covada Group.

Covada Group

Omm

Covada Group, undivided (Ordovician?)--Poorly to moderately sorted arkose to subarkosic quartz-feldspar-bearing wacke and quartz-bearing arenite with intercalated greenstone, carbonate, argillite, conglomerate, and basaltic greenstone. Trilobites from limestone interbedded with greenstone indicate an Early Ordovician age for at least that part of the unit (Snook and others, 1981).

These rocks were first mapped in the Covada Mining District by Weaver (1913), who assigned them a Carboniferous age based on their similarity to rocks in the Republic area which had been thought to be Carboniferous. Pardee (1918) named older metasedimentary rocks and greenstone on the Colville Indian

Reservation the Covada Group. He correlated the Covada Group with Carboniferous sedimentary rocks from Alaska to California. Plant fossils, reported to be from the Covada Group near the Silver Leaf mine, were described by David White (in Bancroft, 1914, p. 14-15) to be of Pennsylvanian(?) age. However, neither the fossil nor records of the fossil description can be located in the U.S. Geological Survey archives (J. T. Dutro, Jr., USGS, oral commun., 1988), and the mine appears to be located in contact-metamorphosed rocks, which casts doubt on the validity of this fossil locality. Campbell and Raup (1964) mapped metasedimentary rocks and greenstone on the east side of the Columbia River and correlated these rocks with similar rocks mapped as Covada Group by Pardee (1918). Snook and others (1981) extended the name Covada Group to the Inchelium 15-minute quadrangle and suggested an Ordovician age for the Covada Group, after Early Ordovician trilobites and conodonts were identified by Peter Ward and J. E. Repetski, respectively (in Snook and others, 1981), from two sites on Butcher Mountain. Trilobites and brachiopods from another site on Butcher Mountain were cursorily examined by R. J. Ross, Jr. (Colorado School of Mines, written commun., 1988); these fossils also suggest an Early Ordovician age for at least the limestone and greenstone sequence of the Covada Group on the east side of the Columbia River. Recent work by M. T. Smith and G. E. Gehrels, (Univ. of Arizona, written commun., 1990) indicates that chert-quartz-bearing arenite, conglomerate, and siliceous argillite previously mapped as Covada Group (Snook and others, 1981; Fullmer, 1986) are a younger unit, which they call the Bradeen assemblage, and should be excluded from the Covada Group.

The Covada Group is correlated by Smith and Gehrels (1989) with the Lardeau Group in southern British Columbia and the Valmy Formation in the Roberts Mountains Allochthon in Nevada, which also contain texturally mature quartz arenite and arkosic sediments. Basaltic greenstones and a probable fault-bounded lens of quartzo-feldspathic wacke and arenite in the Kettle Falls area on the Republic and Colville 1:100,000-scale quadrangles are also correlated by M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) with the Covada Group.

U/Pb dating of detrital zircons suggests a heterogenous early Proterozoic source area for the coarse clastics in the Covada Group (Smith and Gehrels, 1989).

The Covada Group has been subdivided into greenstone, carbonate rock, and wacke units where exposures are large enough to show at the scale of this map.

Omv

Greenstone--Massive to schistose, green to dark-gray greenstone, basalt, breccia, pyroclastic flows, and pillowed lava interbedded with numerous 2- to 5-m-thick units of dark-gray to black, thinly laminated argillite, volcaniclastic rock, chert, graywacke, dolomite, and lenses of recrystallized limestone (Smith, 1982). In thin section the greenstone is made up of chlorite, laths of albite, lamellar aggregates of biotite, fibrous crystals of tremolite and actinolite, and minor amounts of epidote, clinozoisite, and titanite (Fullmer, 1986); outlines of relict amphibole and pyroxene are present (Smith, 1982). What may have been phenocrysts of olivine are completely replaced by serpentine; relict augite crystals are partially or entirely replaced by actinolite (Smith, 1989). The rock contains disseminated pyrrhotite and pyrite and vesicles are filled with sparry calcite. Geochemical analyses of several samples (Smith, 1989) indicate that the massive greenstone and pillow lavas are alkali basalt that has a relatively high Ti content and a low Y:Nb ratio.

Tuff ranges from finely laminated ash-tuff to coarse lapilli tuff; it is commonly present in metasedimentary units as thin layers and lenses (Smith, 1989). Coarse tuff is massive and includes well-sorted angular clasts. Lahar-like deposits with poorly sorted limestone and argillite clasts in a mudstone matrix are present near Gifford (Smith, 1982). The unit generally has sharp contacts with sedimentary units (Fullmer, 1986).

Early Ordovician trilobites from volcaniclastic rock interbedded with the basaltic greenstones on Butcher Mountain (W1/2SW1/4SW1/4 sec. 2, T. 33 N., R. 37 E.) were identified by Peter Ward (in Snook and others, 1981) and include Moxomia n. sp., Pliomeroides sp. indet., Geragnostus curvata?, and Asaphellus sp.

Ocb

Carbonate rock--Light- to medium-gray, well-bedded to massive limestone, dolomite, and impure marble. Smith (1989) has identified three occurrences of limestone in the Covada Group: (1) Medium-gray and recrystallized limestone in 1- to 10-m-thick lenses in the eastern part of the Covada Group. The lenses, which are sandy in places and have phyllitic partings, are in the greenstone unit and at the contacts of the greenstone with metasedimentary rocks. (2) Carbonate along Jones Creek that ranges from massive, fetid, limestone and dolomite in the western part to calcareous phyllite to the east. Contacts with the adjacent siliciclastic rocks of the Covada Group are poorly preserved and not well understood. This large carbonate body is in probable fault contact with higher grade metamorphic rocks to the south, and may stratigraphically overlie or interfinger with metasedimentary rocks of the Covada Group to the east. (3) White to gray marble and gray to greenish calc-silicate rocks with wollastonite and pyrite interbedded with thin-bedded, medium-gray, argillaceous calcite marble adjacent to the porphyritic granodiorite of Manila Creek.

Few fossils have been found in the Covada Group. Conodonts from limestone interbedded with greenstone and argillite on Butcher Mountain (W1/2SW1/4NW1/4,SW1/4 sec. 2, T. 33 N., R. 37 E.) were described by J. E. Repetski (in Snook and others, 1981) and include ?Acanthodus lineatus (Furnish); Drepanoistodus forceps (Lindstrom); c.f. Drepanodus arcuatus Pander (sensu van Wamel, 1975); and Scolopodus rex Lindstrom, which suggest a medial to early Early Ordovician age. Smith (1989) reports small, unidentified gastropods from massive gray dolomite west of the Shamrock mine in the large body of carbonate in Jones Creek.

Ow

Wacke and quartzite--Light-gray to brown to olive-green, moderately to poorly sorted, medium- to thick-bedded, medium-grained to granular quartz-feldspar subarkosic wacke, arenite, and rare quartz arenite, with slaty interbeds. Wacke is the dominant lithology west of the Columbia River, especially west of Wilmont Creek; subarkosic arenite is more common east of the Columbia River. Coarser rocks typically have a "gritty" appearance, with granule-size bluish quartz eyes and feldspar grains in a medium-grained quartz-rich matrix.

Subangular to rounded, fine-sand- to granule-size grains include, in order of decreasing abundance: monocrystalline quartz, K-feldspar, plagioclase, polycrystalline quartz, muscovite, tourmaline, and zircon; biotite and sedimentary lithic grains are locally common, but generally absent. The matrix makes up 10 to 50 percent of the rock (Smith, 1982) and is typically recrystallized. It includes fine-grained chlorite, muscovite and/or sericite, albite, quartz, titanite, and opaque minerals. Biotite is a constituent of the matrix in rocks of higher metamorphic grade (Smith, 1989). Quartz is generally of plutonic origin; quartz from metamorphic rocks constitutes no more than 20 percent (Smith, 1982). Some quartz contains rutile (Janzen, 1981). Feldspars are dominated by sodic plagioclase; microcline constitutes less than 20 percent of the total feldspar.

Primary structures are rare but include graded beds in wacke beds and small-scale crossbeds. Bouma AE divisions, typical of proximal turbidities, are present throughout the section.

The unit is hornfelsed north of Adams Mountain near the contact with Tertiary-Cretaceous intrusive rocks and upgraded to a garnet-kyanite schist near the contact with the porphyritic granodiorite of Manila Creek (EPA ia$_m$) on the west side of the Columbia River (Smith, 1989).

Rocks East of the Huckleberry Range Fault

Dcb

Carbonate rock (Devonian)--Small body of medium-gray, medium-bedded, fossiliferous limestone that crops out on the north side of the Springdale-Hunters road across from the Greenwood Cemetery. Conodonts (USGS colln. 9682-SD), including Apatognathus varians Branson & Mehl, coniform elements of an icriotontid, Polygnathus communis communis Branson & Mehl, and P. semicostatus Branson & Mehl, were identified by A. G. Harris (USGS, written commun., 1978, 1990) and are of middle to late Famennian age (no older that the lower Marginifera Zone. This determination is compatible with the Late Devonian (mid-Famennian) age of the brachiopods identified by J. T. Dutro, Jr. (in Dutro and Gilmour, 1989) which include Thiemella? sp., Schizophoria cf. S. australis Kindle, Uchtospirfer? cf. U. kindlei (Stainbrook), and Tylothyris? cf. T. raymondi (Haynes). Other fossils in the limestone include echinoderm, horn coral, and pelecypod fragments. Contact relations are unknown, but the limestone is presumed to be fault-bounded.

Omm_l

Ledbetter Slate (Ordovician)--Interbedded dark-gray to black, thin-bedded, fissile, carbonaceous slate, argillite, siltite, siliceous argillite, and calcareous argillite dominantly composed of very fine grained quartz and carbonaceous material and varied amounts of calcite, dolomite, and pyrite. Carbonate-bearing rocks are generally in the lower and the middle part of unit. The Ledbetter Slate is approximately 1,200 m thick on the Nespelem quadrangle (Abrams, 1980). Silicification is common where the unit is in contact with intrusive rocks (Smith, 1982). The contact with the Metaline Formation is conformable; the contact with Bradeen assemblage is everywhere covered but presumed to be a fault (Snook and others, 1981; Campbell and Raup, 1964).

Middle Ordovician (Llanvirnian) graptolites, which include Climacograptus cf. C. bicornis; Glossograptus sp.; Orthograptus 2 spp. (cf. Calcaratus); Dicellograptus sp.; Dicranograptus sp. (cf. D. nicholsoni), have been identified (R. J. Ross, Jr., in Snook and others, 1981) and are known from five sites in the Ledbetter Slate in the Nespelem quadrangle.

Dark-gray to black, thin, horizontally laminated microcrystalline chert and interbedded brown, thinly laminated siliceous argillite and siltite are present stratigraphically above the Metaline Formation and thought to be in part equivalent to the Ledbetter Slate (Campbell and Raup, 1964; Snook and others, 1981). The chert is also interbedded with lenses and thinly laminated beds of limestone which increase in thickness to the south (Campbell and Raup, 1964). The siliceous units are cut by stringers and boxworks of quartz and limonite.

$O\text{Є}cb_m$

Metaline Formation (Middle Cambrian to Middle Ordovician)--Limestone with slate and dolomite. The basal part of the unit contains interbedded, thin-bedded, gray-green limestone, siltite, and dolomite. The upper part of the unit is generally recrystallized, locally fetid, pyritic, massive blue-gray limestone with abundant slate interbeds that contain bedded black chert nodules, intraformational breccias, oncolites replaced by calcite, and algal structures (Lucas, 1980). The Metaline Formation is more than 800 m thick in the Nespelem quadrangle (Smith, 1982). The age of the formation is based on conodonts, vertebrates (Repetski, 1977; Repetski and others, 1989), and graptolites (Carter, 1989) identified in the Colville 1:100,000-scale quadrangle. The contact with the overlying Ledbetter Slate is gradational.

Part of the Metaline Formation was originally called the Old Dominion limestone by Weaver (1920); the name was given to diverse limestones thought to be Cambrian to Carboniferous in age that are in a belt from Aladdin in the Colville 1:100,000-scale quadrangle to Dunn Mountain in the Chewelah 1:100,000-scale quadrangle. Campbell and Raup (1964) restricted the name to Cambrian limestone in the Hunters 15-minute quadrangle in the southeast corner of the Nespelem quadrangle. Snook and others (1981) and Snook and others (1990) called carbonate rocks of Cambrian age on the Inchelium quadrangle the Metaline Formation. The Old Dominion limestone, as mapped by Campbell and Raup (1964), has similar lithology and holds the same stratigraphic position as the Metaline Formation (Lindsey, 1987). J. E. Schuster (in Lindsey, 1987) suggests that the name Metaline Formation be used in place of Old Dominion, as has been done where appropriate, for rocks originally called Old Dominion by Weaver (1920) on the geologic map of the west half of the Sandpoint 2° quadrangle (Miller and Yates, 1976).

$\text{-€}ph_m$

Maitlen Phyllite (Lower Cambrian)--Green-gray and tan argillite and siltite interlaminated with thin-bedded quartzite and argillite. Snook and others (1981) estimate the thickness to be 180 m in the Inchelium 15-minute quadrangle. Vacher (1969) indicated that the Maitlen Phyllite is 656 m thick in the Nespelem quadrangle; however, this figure likely includes rock now generally assigned to the Addy Quartzite. In the Chewelah 1:100,000-scale quadrangle Lindsey (1987) measured 200 m of argillite which was assigned by Lucas (1980) to the Maitlen Phyllite.

$\text{-€}Zq_a$

Addy Quartzite (Lower Cambrian-Precambrian Z)--Chiefly thick-bedded, medium-grained to granular, white to buff to gray and purplish, cross-bedded quartzite interbedded with thin- to medium-bedded siltite and argillite. The formation has been subdivided into four subunits by Lindsey (1990). It was named by Weaver (1920) for exposures in the Iron Mountains near Addy in the Chewelah 1:100,000-scale quadrangle. The unit is estimated to be 1,200 to 1,450 m thick (Lindsey, 1990). It unconformably overlies the conglomerates of the Huckleberry Formation on Adams Mountain (Lindsey, 1987).

The formation contains horizontal trails of Cruziana and Planolites and vertical burrows of Scolithus linearis and S. bulbus. Early Cambrian trilobites have been found in the upper 500 m of the unit in the Chewelah 1:100,000-scale quadrangle. The lack of trilobites in rocks of similar lithology and environment of deposition lower in the section led Lindsey (1987) to conclude that the trilobites in the upper part of the Addy Quartzite are the "evolutionary" first appearance of that fossil and that the Precambrian-Cambrian boundary may lie in the lower half of the Addy Quartzite. The unit is correlated with the Gypsy Quartzite on the basis of their similar lithology and stratigraphic positions. However, the Gypsy Quartzite may be slightly older than the Addy Quartzite because the Early Cambrian fauna first appears higher in the Gypsy Quartzite (Lindsey,1987).

Precambrian Metasedimentary and Metavolcanic Rocks

Windermere Group

The greenstone member (Zmv) and the conglomerate member (Zcg) of the Huckleberry Formation comprise the Windermere Group in this quadrangle. These rocks were deposited in fault-bounded basins formed during rifting of the North American continent in the late Proterozoic (Lis and Price, 1976) to early Cambrina (Devlin and others, 1988). The Windermere Group is thicker and is present as a more complete section in the Colville and Chewelah 1:100,000-scale quadrangles. It unconformably overlies the Deer Trail Group and is conformable overlain by the Addy Quartzite in the Nespelem 1:100,000-scale quadrangle.

Zmv_h, Zcg_h

Huckleberry Formation (Precambrian Z)--The unit was first recognized by Jones (1928) and was named the Huckleberry Greenstone and Huckleberry Conglomerate by Bennett (1941). The formation was given formational status by Campbell and Loofbourow (1962), who designated the two distinct lithologic types as members.

Zmv_h

Greenstone member--Fine-grained basalt flows and pyroclastic rocks. Flows are aphyric to porphyritic with as much as 10 percent phenocrysts, which are chiefly plagioclase (An_{45}). Plagioclase as phenocrysts and in the groundmass is replaced by epidote, clay, chlorite, pumpellyite, and titanite. Mafic minerals, which compose as much as 50 percent of the rock, are completely altered to chlorite, titanite, leucoxene, and tremolite. Calcite and/or epidote and chlorite fill amygdules; pillows are rare. The greenstone is locally schistose. The unit is estimated to be a maximum of 900 m thick. The contact with the overlying Addy Quartzite is conformable and is gradational with conglomerates of the Huckleberry Formation. The greenstone member is correlated with the Leola Volcanics in the Colville 1:100,000-scale quadrangle. The greenstone member thins to the south from Stensgar Mountain in the Chewelah 1:100,000-scale quadrangle (Campbell and Loofbourow, 1962). K-Ar ages on samples from the Iron Mountains in the Chewelah 1:100,000-scale quadrangle are 827 and 918 Ma (Miller and others, 1973). Devlin and others (1985) examined rocks from the same site and found that the Rb/Sr isotopic system of these rocks had been severely disturbed, suggesting that the K/Ar ages of Miller and others (1973) are probably not their age of extrusion. More recent Sm/Nd whole-rock and mineral separation data from the base of the Huckleberry Formation (Devlin and others, 1988) suggest that extrusion of the volcanic rocks occurred at 762 ± 44 Ma.

Zcg_h

Conglomerate member--Well-foliated, greenish- to olive-gray, poorly sorted conglomerate (Campbell and Raup, 1964). The unit contains angular to subrounded clasts of slate, phyllite, argillite, limestone, dolomite, and quartzite in a chloritic matrix, which is in part tuffaceous (Campbell and Loofbourow, 1962). The conglomerate is approximately 200 to 500 m thick (Evans, 1987), but it is not present south of the Turk mine (sec. 6, T. 29 N., R. 38 E.) (Campbell and Loofbourow, 1962). This member unconformably overlies the Buffalo Hump Formation; in some places it thins or is faulted out, so that the greenstone member (Zmv_h) lies directly on the Buffalo Hump Formation (Campbell and Loofbourow, 1962). The member is correlated with the Shedroof Conglomerate in the Colville 1:100,000-scale map area.

Deer Trail Group

The Deer Trail Group is composed of 2,200 m of argillite, siltite, quartzite, and dolomite. The group has been correlated by Miller and Whipple (1989) with the Belt Supergroup.

Yq_b, Yar_b

Buffalo Hump Formation (Precambrian Y)--Quartzite and argillite; defined by Campbell and Loofbourow (1962) as rock above the Stensgar Dolomite and below the Windermere Group. The amount of argillite varies throughout the section and is the dominant lithology at the top and base of the formation. Variations in relative abundances of argillite and quartzite from north to south have been noted by Campbell and Raup (1964) and Campbell and Loofbourow (1962); however, some of the observed variation may be due to faulting, folding, and poor exposure (Miller and Whipple, 1989). The formation is estimated by Miller and Whipple (1989) to be approximately 520 m thick in the Chewelah 1:100,000-scale quadrangle. The Buffalo Hump is overlain by the Windermere Group rocks with an erosional unconformity and conformably overlies the Stensgar Dolomite. It is correlated with units C and D of the Striped Peak Formation in the Pend Oreille valley by Miller and Whipple (1989).

Yq_b

Quartzite--Vitreous to subvitreous, medium- to thick-bedded, poorly sorted and bedded, gray-white to yellow-brown to pinkish vitreous quartzite, and green, hematite-red and gray, even-parallel and cross-bedded quartzite and siltite that is locally feldspathic. Sedimentary features are more defined where the sorting is better. In places, vitreous quartzite is very coarse grained to pebbly and has an argillaceous matrix. The unit is approximately 300 m thick in the Chewelah 1:100,000-scale quadrangle (Miller and Whipple, 1989).

Yar_b

Argillite--Light- to dark-gray and brown-green, thinly laminated argillite and phyllite. Argillite and phyllitic argillite at the base of the formation is greenish-gray to dark-gray and has even-parallel laminae and microlaminae. The amount of argillite is varied, but it is most abundant at the top and the base. Miller and Whipple (1989) report a 220-m-thick section of argillite at the top of the section, which is similar to that at the base except that it includes a 30- to 50-m-thick quartzite section. Where cleavage can be distinguished from bedding, the cleavage angle differs from that of the underlying McHale Slate (Campbell and Loofbourow, 1962).

Ycb_s

Stensgar Dolomite (Precambrian Y)--Thin-bedded, tan, pinkish-maroon to light-gray, fine- to coarse-grained, fairly pure dolomite interlaminated with minor quartzite and maroon argillite; locally altered to magnesite. At the Jim McGraff quarry area in the Chewelah 1:100,000-scale quadrangle, sparse algal structures, ooliths, and casts of evaporite minerals are present (Miller and Whipple, 1989). This unit is overlain with apparent conformity by the Buffalo Hump Formation in the Hunters 15-minute quadrangle (Campbell and Loofbourow, 1962); the contact with the Buffalo Hump in the Chewelah 1:100,000-scale quadrangle is reported to be everywhere a fault or sheared contact (Miller and Whipple, 1989). South of the Spokane Indian Reservation in the Coulee Dam 1:100,000-scale quadrangle, the Stensgar either pinches out due to nondeposition, is cut out by a small erosional unconformity, or is faulted out so that the slate of the Buffalo Hump immediately overlies the McHale Slate (Campbell and Loofbourow, 1962). The Stensgar Dolomite is approximately 200 to 250 m thick. The unit was named by Weaver (1920) and given formational status by Bennett (1941) when the Deer Trail argillite was upgraded to the Deer Trail Group. It is correlated with units B and A of the Striped Peak Formation in the Pend Oreille River valley by Miller and Whipple (1989).

Yar_m

McHale Slate (Precambrian Y)--Olive-gray, greenish-gray and locally purplish-gray, thin- to very thin bedded argillite (Campbell and Loofbourow, 1962) composed of angular grains of quartz and feldspar as large as 0.05 mm. Muscovite, chlorite, pumpellyite, pyrite, titanite, and stilpnomelane are locally abundant; calcite, carbonaceous material, hematite, leucoxene, magnetite, and tourmaline are minor constituents (Evans, 1987). Bedding in the lower part ranges from sub-millimeter-thick laminations to fining-upward graded couplets as much as 30 mm thick; even-parallel laminations and soft-sediment deformation are common. Bedding in upper part is almost entirely even parallel; soft-sediment deformation is rare. Slatey cleavage is common (Campbell and Loofbourow, 1962). The McHale Slate is estimated to be 370 m thick in the Chewelah 1:100,000-scale quadrangle (Miller and Whipple, 1989). It conformably overlies the Edna Dolomite. The upper 20 to 30 m appears to be gradational with the Stensgar Dolomite (Miller and Whipple, 1989).

Ycb_e

Edna Dolomite (Precambrian Y)--Dolomite containing units of quartzite and argillite. Thin- to very thin bedded, parallel to wavy nonparallel bedded, cream to light-gray and black, fine-grained dolomite is the dominant lithology. Chert-bearing dolomite is common, but not abundant. The unit generally has higher silica and lower magnesium contents than the Stensgar Dolomite (Campbell and Raup, 1964), and it weathers to a distinctive brick-red soil. Stromatolitic beds are common in the dolomite (Miller and Whipple, 1989). South of the Hunters-Springdale road, dolomite is metamorphosed to fine-grained, dark-green, diopside-bearing hornfels (Campbell and Loofbourow, 1962). Bluish-gray, light-gray, and buff, fine-grained, thick- to thin-bedded, vitreous quartzite is present as thin discontinuous zones in the middle and uppermost parts of the formation along the entire exposure of the Deer Trail Group (Miller and Whipple, 1989). Light-gray to pale-green, thin-bedded argillite and slate is interbedded with carbonate-bearing quartzite and siltite and minor carbonate beds in the lower part of the formation (Miller and Whipple, 1989). Cleavage in the argillite and slate is paper thin (Campbell and Loofbourow, 1962). The formation was named by Campbell and Loofbourow (1962). The upper part of the formation is correlated by Miller and Whipple (1989) with the Shepard Formation in the Pend Oreille River valley.

Yar_t, Yq_t

Togo Formation (Precambrian Y)--Medium- and dark-gray argillite with units of quartzite or dolomite. Because the base of the unit is not exposed and the formation is complexly folded, Miller and Whipple (1989) have indicated that the maximum original thickness can only be estimated at greater than 650 m and that the formation may be thinner than the 1,200 m originally estimated by Campbell and Loofbourow (1962). The formation was named by Campbell and Loofbourow (1962) and has been correlated by Miller and Whipple (1989) with the Wallace Formation in the Pend Oreille River valley. Two lithologic subunits of the Togo Formation have been mapped:

Yar_t

Metasedimentary rocks, undivided--Interbedded, thin-bedded, medium- to dark-gray argillite, phyllite, and siltite, and a few sharply defined units of quartzite or dolomite. These rocks are composed of fine-grained quartz, K-feldspar, biotite, muscovite, and clay and contain stilpnomelane and titanite, probably of metamorphic origin, and locally abundant allanite, carbonate, pyrite, and iron oxides (Evans,1987). Minor conglomerate consists of quartz and feldspar clasts in a matrix of quartz, K-feldspar, muscovite, and biotite (Henderson, 1983; Evans, 1987). Distinctive thin beds of laminated black and white argillite are present near the top of the formation (Campbell and Loofbourow, 1962). The unit also includes grayish-blue carbonate rock that contains 80 percent dolomite and calcite, 10 percent tremolite, 5 percent hornblende, and minor chalcopyrite (Henderson, 1983).

Yq_t

Quartzite--Fairly pure quartzite interbedded with dark-gray argillite and slatey quartzite. The grayish-pink to white, thin-bedded, fine-grained to granular quartzite is subvitreous to vitreous (Henderson, 1983).

Intrusive Igneous Rocks

Tertiary Hypabyssal Intrusive Rocks

Eir

Intrusive rhyolite near West Fork (Eocene)--Light-colored dikes and plugs that consist of dense, dark-gray, aphyric rhyolite with distinctive conchoidal fracture and that contains 3 to 5 percent microphenocrysts of biotite and subhedral and unzoned plagioclase (An_{33-37}) in a glassy or devitrified groundmass of quartz and K-feldspar (Moye, 1984). The rhyolite intrudes the Sanpoil Volcanics, with no thermal effects, in the central and eastern part of the Republic graben (Atwater and Rinehart, 1984; Moye, 1984). It is chemically distinct from Klondike Mountain Formation in the northern part of Republic graben, but may be comagmatic with the granite of Deadhorse Creek (Eig_{dh}) and aplite dikes that cut the hypabyssal dacite dikes (Eida) (Atwater and Rinehart, 1984). The rhyolite forms domes associated with strongly developed northeast-trending topographic lineaments. At least one dome is associated with an explosion breccia, suggesting that some domes vented to the surface (Moye, 1984). A K-Ar age on biotite is 49.5 ± 0.3 Ma (Atwater and Rinehart, 1984).

Eida, ++++

Hypabyssal dacite dikes (Eocene)--Hypabyssal, hornblende-biotite and biotite dacite dikes and small plugs. Different names for dikes of similar chemical composition and mineralogy are: Scatter Creek Rhyodacite of Muessig (1967), Staatz (1964), Atwater and Rinehart (B. F. Atwater and C. D. Rinehart, USGS, written commun., 1989); hypabyssal intrusive suite of Cody Lake of Atwater and Rinehart (1984); Tsh_1 and Tsh_2 of the Colville Confederated Tribe Geology Department (1984); quartz latite dikes of Smith (1982) and Abrams (1980) and andesite porphyry dikes of Campbell and Raup (1964). As mapped, the unit includes the boulder-bearing rhyolite porphyry of Thirty Mile Creek of Moye (1984). The unit is mapped with a stipple pattern where dikes swarms are estimated to exceed 10 percent of rock and mapped as Eida where country rock appears to be entirely absent. The unit consists of two phases:

(1) A younger phase, biotite-hornblende-bearing dikes composed of medium- to dark-gray, porphyritic dacite to andesite. Phenocrysts make up 20 to 50 percent of the rock. Zoned and unzoned, subhedral to euhedral plagioclase phenocrysts (An_{30-66}) constitute as much as 35 percent of the rock and are typically twinned or in rosettes as much as 2 cm in length. Biotite is reddish brown and is present as subhedral and euhedral phenocrysts that comprise less than 10 percent of the rock. Minor augite (5%) forms mafic clots or cores in hornblende phenocrysts; quartz and sanidine phenocrysts are rare. This phase contains minor titanite, apatite, magnetite, zircon, and epidote. The fine-grained to glassy matrix contains quartz, and plagioclase (Atwater and Rinehart, 1984; Holder, 1986; Moye, 1984). These dikes cut light-colored hypabyssal biotite-bearing dikes and Keller Butte suite intrusive rocks, but cut younger plutons in only a few places. Devils Elbow monzodiorite, Kettle Crest pluton, and Fire Mountain pluton either have or grade into dikes in the roof or the margin of intrusions (Holder, 1985; Holder, 1986). On the east side of the Devils Elbow monzodiorite ($Eimd_d$), biotite-hornblende-bearing dikes form an intrusive complex that is gradational over 20 m into the monzodiorite (Carlson, 1984). The biotite-hornblende-bearing dikes cut O'Brien Creek Formation (Holder, 1986) and intrude, yet are thought to be feeders of the Sanpoil Volcanics (Moye, 1984). The northeast strike of the dikes suggests that the trend of dikes was controlled by structures related to the Republic graben (Moye, 1984). A K-Ar age on biotite is 50.3 ± 0.3 Ma and on hornblende, 49.4 ± 0.3 Ma (Atwater and Rinehart, 1984). A dike on Miller Mountain south of the Columbia River yielded K-Ar ages on biotite of 49.2 ± 0.3 Ma and, on hornblende, of 53.8 ± 3.1 Ma (B. F. Atwater, USGS, written commun., 1987).

(2) An older phase, biotite-bearing dikes composed of light-gray aphanitic dikes with 25 to 40 percent plagioclase, biotite, and quartz phenocrysts. Plagioclase (An_{35-40}) as single laths and glomeroporphyritic clots makes up 30 to 40 percent of the phenocrysts. Quartz comprises only 1 to 2 percent of the phenocrysts (Carlson, 1984). These dikes are thought to be the intrusive equivalent of the O'Brien Creek Formation; they grade up into tuff and lavas of that formation (Colville Confederated Tribes Geology Department, 1984). These dikes also cut Keller Butte suite plutons and are truncated by at least one Herron Creek suite intrusion (Holder, 1986). Their overall trend is parallel to the Republic graben, but in detail the dikes bifurcate and terminate in en echelon segments (Carlson, 1984).

Plutonic Rocks

Tertiary Intrusive Rocks West of the Columbia River

Herron Creek suite

Five units of the Herron Creek suite (HCS) (Eig_v, Eig_{dh}, Eig_g, $Eiqm_f$, $Eigd_j$) are present in the Nespelem quadrangle. The rocks are dominantly calc-alkalic to alkali-calcic, undeformed, medium- to coarse-grained or fine-grained, biotite-hornblende quartz monzonite to granite. Rocks of the suite cut and locally contain inclusions of foliated rocks of the Devils Elbow suite. They are modally distinct from and more K_2O rich, relative to SiO_2, than the Devils Elbow suite. The suite is thought to be coeval with upper flows of the Sanpoil Volcanics and subvolcanic feeder dikes (hypabyssal dacite dikes). The intrusion of the HCS predates the last movement along graben-bounding faults; it may postdate deformation associated with the metamorphic core complexes (Holder and others, 1989).

Eig_v

Varied granite near Stepstone Creek (Eocene)--Small body of leucrocratic (color index 5) massive, fine-grained biotite granite with characteristic marked textural variation. The granite is generally equigranular; biotite ranges 0.1 to 2.5 mm and is locally present as clots. Rare, fine-grained (0.1 mm) hornblende crystals are also present. The pluton cuts the medium-grained granite of Moses Mountain EP i_{qm}) and the hornblende-biotite-bearing hypabyssal dacite dikes (Eida) (Atwater and Rinehart, 1984; R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

Eig_{dh}

Granite of Deadhorse Creek (Eocene)--Inequigranular, medium- to coarse-grained biotite granite. Quartz, orthoclase, and plagioclase make up 95 percent of the rock; 1.5-mm subhedral grains of biotite comprise 5 percent. Quartz crystals are 3 to 5 mm in diameter and have straight boundaries with feldspar. Plagioclase (An_{39-44}) is weakly zoned and displays well-developed twinning (Holder, 1986). No noticeable chill margin is present at the contact with the Devils Elbow monzodiorite ($Eimd_d$); in places, the contact consists of swirled layers of hornblende-biotite-rich bands and light-colored bands more than 30 m thick, suggesting that the Devils Elbow monzodiorite had not completely cooled before intrusion of the Deadhorse Creek pluton (Carlson, 1984). This granite may be equivalent to intrusive rhyolite near West Fork (Eir) (Atwater and Rinehart, 1984). The granite of Deadhorse Creek lacks the intensive dike development of other plutons in the area, suggesting that the magma body was not subjected to significant extension. Aplite dikes, associated with the pluton, that intrude the Devils Elbow monzodiorite do not have strong regional trends (Holder, 1986). Intrusive textures suggest that the pluton formed at higher temperature and at shallower depths than other Eocene plutons in the area (Carlson, 1984). Biotite yielded a K-Ar age of 49.6 ±0.3 Ma (Holder, 1986).

Eig_g

Granite Mountain pluton (Eocene)--Brown to gray, fine-grained (0.5-1 mm) hornblende-biotite granodiorite to granite with minor plagioclase phenocrysts. The pluton contains euhedral to subhedral plagioclase (An_{55} in the core, An_{13} on the rim); euhedral to anhedral orthoclase that is typically altered to microperthite, with inclusions of plagioclase, biotite, and hornblende; anhedral quartz that commonly displays undulose extinction adjacent to the Sherman fault; black biotite; and minor hornblende. Accessory minerals include euhedral magnetite, apatite, titanite, zircon, and allanite (Holder, 1985). The pluton consists of six individual bodies that trend parallel to the Republic graben; the pluton was included with the granite of Deadhorse

Creek by Atwater and Rinehart (1984), but was mapped as a separate body by Holder (1985). This pluton is bounded by the Sherman fault on the north. Other contacts are intrusive and gradational over 15 to 50 m. Dikes of the pluton cut the Fire Mountain pluton ($Eiqm_f$) and the Kettle Crest pluton ($Eimd_k$). Faint foliation locally parallels the contact with the Fire Mountain pluton (Holder, 1985).

$Eiqm_f$

Fire Mountain pluton (Eocene)--Medium- to coarse-grained, pyroxene-biotite-hornblende monzonite, monzogranite, and monzogabbro containing pink and gray orthoclase phenocrysts. Hornblende is generally cored by clinopyroxene. Orthoclase is poikilitic and locally forms microperthitic clots. Plagioclase (An_{45-48} in cores, An_{13-15} in rims) is euhedral and subhedral. Biotite is commonly chloritized and forms reaction rims on hornblende. Anhedral quartz is the only mineral that exhibits effects of strain. Accessory minerals include magnetite, titanite, apatite, zircon, and allanite. The pluton contains miarolitic cavities. Calc-silicate skarns are developed locally in more lime-rich xenoliths. The pluton is elongate parallel to the Republic graben and grades into hypabyssal dacite dikes (Eida); it intrudes the Kettle Crest pluton ($Eimd_k$) with a sharp contact. The pluton has no tectonic fabric, but it truncates fabric formed in the Kettle Crest pluton and granitic orthogneiss and metasedimentary rocks of the Hall Creek gneisses (Holder, 1985).

$Eigd_j$

Granodiorite of Joe Moses Creek (Eocene)--Fine- to medium-grained, inequigranular hornblende-biotite granodiorite to granite with equant plagioclase phenocrysts in a fine-grained ground mass. In the groundmass plagioclase is An_{38-19} and orthoclase is present as anhedral grains. Quartz forms anhedral and composite grains. Accessory minerals include magnetite, apatite, and zircon (Carlson, 1984). The unit is cut by biotite-hornblende-bearing hypabyssal dacite dikes and cuts porphyritic granite of the Keller Butte, as well as Devils Elbow monzodiorite (Atwater and Rinehart, 1984). The pluton abuts the Sherman fault, but it is not displaced or affected by cataclasis associated with the fault (Carlson, 1984). Biotite yielded a K-Ar age of 49.7 ± 0.4 Ma (B. F. Atwater, USGS, written commun., 1987).

Devils Elbow suite

Three units of the Devils Elbow suite (DES) are shown on Plate 1. The suite is composed of calc-alkalic, medium-grained, biotite-hornblende quartz diorite, quartz monzonite, and granodiorite plutons that crosscut less mafic rocks of the Keller Butte suite. The DES is associated with HCS intrusions; contacts with the HCS range from gradational to razor sharp so that relative ages are difficult to determine. Where adjacent to the Kettle gneiss dome, the plutons are mildly affected by deformation associated with core complex development (Holder, 1985; Holder, 1986). Plutons of the DES are elongate parallel to the Republic and Keller grabens (Holder and others, 1989; Holder and Holder, 1988).

$Eimd_{lm}$

Diorite of Little Moses Mountain (Eocene)--Fine- to medium-grained hornblende diorite in small dike-like bodies in the valley of Stepstone Creek. The unit intrudes medium-grained granite of Moses Mountain and/or is cut by dikes of the varied granite of Stepstone Creek (Atwater and Rinehart, 1984).

$Eimd_k$

Kettle Crest pluton (Eocene)--Leucocratic (color index 15-25), weakly foliated, medium-grained, equigranular, gray, homogeneous biotite-hornblende monzodiorite to monzogabbro. Plagioclase forms euhedral, twinned, normally zoned (An_{43} at the core, An_{28} at the rim) crystals. Slightly strained anhedral quartz and minor anhedral orthoclase are interstitial to plagioclase, biotite, hornblende, and clots of mafic minerals. Weak foliation is defined by biotite and hornblende. The pluton contains miarolitic cavities. It cross-cuts fabric in country rocks on regional and local scales; it is locally truncated by faults defining the Republic graben. It was emplaced during the waning stages of formation of the Kettle gneiss dome (Holder, 1986). K-Ar ages of 45.2 ± 1.1 Ma (biotite) and 47.7 ± 1.2 Ma (hornblende) have been obtained (B. F. Atwater, USGS, written commun., 1987).

$Eimd_d$

Devils Elbow monzodiorite (Eocene)--Medium-grained, mostly equigranular, biotite-hornblende diorite to granite. The pluton is crudely zoned by the ratio of feldspar to quartz; it is quartz monzonite to granodiorite to the north and hornblende-rich monzodiorite to the south. Plagioclase is zoned (An_{41} in the core, An_{27} in the rim). Hornblende locally forms rosettes of single crystals, which commonly contain cores of pyroxene. Biotite forms psuedohexagonal tablets and reaction rims on hornblende. Plagioclase and minor anhedral quartz and orthoclase are interstitial to other minerals. Accessory minerals include titanite, apatite, zircon, and magnetite (Carlson, 1984). The monzodiorite is cut by the granodiorite of Joe Moses Creek and the granite of Deadhorse Creek (HCS) (Holder, 1986). This pluton is presumed to be source of hypabyssal biotite-hornblende dikes (Colville Confederated Tribes Geology Department, 1984). Biotite has yielded K-Ar ages of 49.6 ± 1.2 Ma and 49.9 ± 0.3 Ma (Atwater and Rinehart, 1984).

Keller Butte suite

Several units of the Keller Butte suite (KBS) are mapped; they generally consist of fine- to very coarse grained, light-colored, hornblende-free, biotite (± muscovite) granite and granodiorite associated with abundant alaskite pegmatite veins, dikes, and pods. The plutons are calcic, and SiO_2 content is greater than 65 percent; the MgO content is low relative to SiO_2. Widespread penetrative mineral fabric is present, generally with nearly east-west elongation, in or adjacent to gneiss domes (Atwater and Rinehart, 1984; Holder and Holder, 1988). A Paleocene to Eocene age is suggested by K/Ar ages from biotite; however, thermal degradation of biotite in response to emplacement of the younger DES and HCS rocks requires that these ages be regarded as minimum (Holder and others, 1989). Intrusion was contemporaneous with formation of grabens and gneiss domes (Atwater, 1985; Holder and Holder, 1988).

EP ig_m, EP ig_{mf}, EP iaa_m

Granite of Moses Mountain (Eocene-Paleocene)--Zoned leucocratic intrusive body in the northwestern part of the map area that is divided into three phases (Atwater and Rinehart, 1984):

EP ig_m

Medium-grained granite--Leucocratic, medium- to coarse-grained (3 mm average), porphyritic biotite granite with K-feldspar and quartz megacrysts. Anhedral quartz is light gray and ranges from 2 to 8 mm in diameter. Subhedral K-feldspar phenocrysts are 1 to 2 cm long and contain abundant plagioclase inclusions. Biotite is the only mafic mineral and contains sparse aggregates of magnetite. Muscovite is sparse and is present in patches; some of the muscovite may be primary. The granite is pegmatitic to graphic to the south and cuts foliation developed in the metasedimentary rocks in Stepstone Creek. The unit displays weakly developed foliation and lineation that parallels that in the Okanogan gneiss dome (Atwater and Rinehart, 1984; R. W. Holder and G. M. Holder, Southern Georgia College, written commun, 1989).

EPA iaa$_{m}$

Varied granite--Muscovite-biotite granite, alaskite, and aplite dikes and pods with pink and red garnets. The varied texture and composition are probably due to contamination by metamorphic xenoliths. The contact is gradational with the fine-grained phase (EPA i$_{gf}$) over tens of meters, but the unit typically has a sharp contact with porphyritic granite of Coyote Creek in the Omak 1:100,000-scale quadrangle (Atwater and Rinehart, 1984). The fabric is well developed, and lineation parallels that in the Okanogan gneiss dome (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

EPA ig$_{mf}$

Fine-grained granite--Leucocratic, fine-grained (2 mm), equigranular granite. Contacts with the younger medium-grained phase are typically gradational over 16 to 320 m. The body is cut by dikes of the varied granite (EPA iaa$_{m}$). The fine-grained granite displays a well-developed fabric with lineation that parallels that in the Okanogan gneiss dome (Atwater and Rinehart, 1984; R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989). A K-Ar age on biotite is 49.4 ± 1.2 Ma, but it may have been reset and should be considered minimum (Atwater and Rinehart, 1984)

EPA ig$_{c}$

Porphyritic granite of Coyote Creek (Eocene-Paleocene)--Leucocratic (color index 3-5), inequigranular, massive, porphyritic biotite granite that typically contains K-feldspar megacrysts (<11 cm) that commonly form clusters. Anhedral, smokey quartz forms rounded crystals or aggregates of crystals 3 to 10 mm in diameter; coarser grained equant quartz is present proximal to K-feldspar megacrysts. Clusters of K-feldspar and quartz megacrysts may locally grade into pegmatite. Medium-grained, anhedral, white plagioclase is restricted to the medium-grained matrix; small amounts of K-feldspar are present in the groundmass. This body lacks a discrete border phase (Atwater and Rinehart, 1984). The granite is cut by a dike of the varied granite of the Moses Mountain granite (EPA iaa$_{m}$) and both phases of hypabyssal dacite dikes (Eida); it intrudes the gneiss and mylonitic rocks near Deerhorn Creek (og$_{d}$) (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989). K/Ar ages on biotite of 50.3 ± 1.5 Ma (Fox and others, 1976) and 51.1 ±1.3 Ma (Atwater and Rinehart, 1984) were returned from the porphyritic granite of Coyote Creek in the Omak 1:100,000-scale quadrangle. The intrusive body generally does not exhibit evidence of ductile deformation; an exception is on the top of Dugout Mountain where a mylonitic fabric has developed with a lineation that parallels that in the Okanogan gneiss dome (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

EPA iaa$_{mg}$, EPA ig$_{mt}$, EPA ig$_{kb}$, EPA ia$_{s}$, EPA ia$_{m}$, EPA ig$_{mc}$

Keller Butte pluton (Carlson, 1984) (Eocene-Paleocene)--Zoned pluton with phases that form a nearly concentric pattern -- from the border inward: coarse-grained porphyry (EPA ia$_{m}$), medium-grained biotite granodiorite (EPA ia$_{s}$), and coarse-grained granite (EPA ig$_{kb}$). The granite porphyry with quartz eyes (EPA ig$_{mt}$) and garnet-bearing leucocratic granite (EPA iaa$_{mg}$) are the youngest phases.

EPA iaa$_{mg}$

Garnet-bearing granite of McGinnis Lake (Eocene-Paleocene)--Leucocratic, fine-grained, locally pegmatitic and aplitic, biotite granite and alaskite that contain 1 to 2 percent pyralspite-series garnet. Quartz is anhedral and turbid due to abundant fluid inclusions. Plagioclase (An_{15-13}) is weakly zoned; orthoclase (Ab_{11}) is anhedral. Accessory minerals include allanite, titanite, zircon, and apatite. This granite intrudes the porphyritic granite of Keller Butte, quartz porphyry of Mount Tolman, granite of Swawilla Basin, and the porphyritic granite of Manila Creek. Quartz crystals are commonly flattened parallel to the contacts with older rocks (Carlson, 1984). Carlson (1984) suggests that the pluton formed from the residual fluid-rich phase of porphyritic granite of Keller Butte, granite of Swawilla Basin, and porphyritic granodiorite of Manila Creek.

EPA ig_{mt}

Quartz porphyry of Mount Tolman (Eocene-Paleocene)--Leucocratic, inequigranular, porphyritic muscovite-biotite granite. Phenocrysts of microcline (2-5 cm) and smaller quartz eyes made up of composite quartz grains that have sutured boundaries are in a fine-grained groundmass that contains euhedral plagioclase (An_{14-12}), microcline, and quartz. The body is generally devoid of accessory minerals (Carlson, 1984). The contact with porphyritic granite of Keller Butte is gradational; the two plutons are probably textural variants of a single pluton (Atwater and Rinehart, 1984). Quartz eyes are locally elongate along the contact with the porphyritic granite of Keller Butte (Carlson, 1984). K-Ar ages on sericite and muscovite are 55.7 ± 2 Ma and 57.7 ± 2.1 Ma, respectively (Atwater and Rinehart, 1984).

EPA ig_{kb}

Porphyritic granite of Keller Butte (Eocene-Paleocene)--Leucocratic, medium- to coarse-grained, equigranular to locally porphyritic, biotite granite at the southern end of the Republic and Keller grabens. Microcline phenocrysts as much as 11 cm in length are common and typically are present in pod-like zones. The groundmass contains subequal amounts of plagioclase (An_{36-15}), orthoclase, quartz, and less than 5 percent slightly altered biotite. Accessory minerals include magnetite, zircon, apatite, and epidote. Pegmatite dikes emanating from the pluton cut the granite of Swawilla Basin and the porphyritic granodiorite of Manila Creek. This granite has a sharp contact with granodiorite of Manila Creek. The pluton is elongate parallel to the graben structure and is cut by Sherman and Manila Pass faults (Carlson, 1984). A K-Ar age on weathered biotite from southern edge of the largest body of pluton is 61.3 ± 2.3 Ma (Atwater and Rinehart, 1984).

EPA ia_s

Granite of Swawilla Basin (Eocene-Paleocene)--Leucocratic (color index 3-5), medium-grained, mostly equigranular, biotite granite and granodiorite. The granite contains white mica northeast of Swawilla Basin, but nowhere is it more abundant than biotite (Atwater and Rinehart, 1984). The unit locally contains 1- to 1.5-cm-long microcline (Ab_{14}) phenocrysts. Plagioclase (An_{22-17}) is weakly zoned. Accessory minerals include allanite, epidote, titanite, apatite, and zircon (Carlson, 1984). The granite is intruded by porphyritic granite of Keller Butte; the contact is gradational over 500 m and dips away from core of the pluton (Carlson, 1984). Biotite yielded a K-Ar age of 58.8 ± 2.2 Ma (Atwater and Rinehart, 1984).

EPA ia_m

Porphyritic granodiorite of Manila Creek (Eocene- Paleocene)--Leucocratic (color index 8-19), medium- to coarse-grained, biotite granodiorite and granite that forms the border of the Keller Butte pluton. This unit contains abundant metasedimentary xenoliths and aligned disc-shaped mafic inclusions as much as 1 m in diameter that resemble titanite-bearing parts of the pre-Tertiary igneous rocks exposed west of the Columbia River (Atwater and Rinehart, 1984). The granodiorite is generally darker in color than the granite of Daisy Trail or granite of Swawilla Basin. Plagioclase is subhedral and locally zoned (An_{36-24}). Microperthitic microcline ($Or_{83}Ab_{17}$) is present only as phenocrysts and contains abundant inclusions of quartz, biotite, and euhedral plagioclase. Biotite is the only mafic mineral and is moderately altered to chlorite, magnetite, and muscovite. Accessory minerals include titanite, apatite, and zircon that generally are present in clusters with biotite (Carlson, 1984). Where present, well-developed foliation and lineation are parallel to structures in the adjacent Covada Group and are locally nearly perpendicular to the overall strike of the contact; elsewhere, granodiorite is not foliated or is weakly foliated. Foliation is generally oblique to the trend of roof pendants. Where roof pendants are exposed at higher levels, the contact is sharp and not chilled. Local andalusite porphyroblasts overprint regional metamorphism (Carlson, 1984). This granodiorite is cut by pegmatite dikes that may emanate from the granite of Swawilla Basin or the porphyritic granite of Keller Butte. The cross-cutting dikes and abundance of metamorphic xenoliths are interpreted as evidence that the Manila Creek granodiorite predates the granite of Swawilla Basin, the porphyritic granite of Keller Butte, and the granite of Daisy Trail (Atwater and Rinehart, 1984).

EPA ig_{mc}

Altered granite of Meadow Creek (Eocene-Paleocene)--Coarse-grained, porphyritic biotite granite that forms a small body approximately 1.6 km south of Keller (Atwater and Rinehart, 1984). The granite is part of the alteration halo associated with the Mount Tolman copper-molybdenum deposit. Biotite and feldspar are generally altered to sericite. The intrusive is cut by a stockwork of quartz veins with varied amounts of pyrite, chalcopyrite, molybdenite, magnetite and sphalerite and abundant limonite. The protolith of the granite may be the porphyritic granodiorite of Manila Creek (Colville Confederated Tribes Geology Department, 1984, Atwater and Rinehart, 1984) or the porphyritic granite of Keller Butte (Atwater and Rinehart, 1984). The altered unit is cut by hypabyssal dacite dikes (Eida) (Atwater and Rinehart, 1984; Colville Confederated Tribes Geology Department, 1984). K-feldspar yielded a K-Ar age of 51.2 ±1.8 Ma (Armstrong and others, 1982).

EPA ia_j

Plutonic complex of Johnny George (Eocene-Paleocene)--Intrusive complex that forms the lower plate of the Lincoln gneiss dome (Atwater and Rinehart, 1984; Colville Confederated Tribes Geology Department, 1984). The unit includes leucocratic intrusive rocks ranging from fine-grained aplite and alaskite through equigranular porphyritic muscovite-biotite granite that resembles the granite of Swawilla Basin. The complex includes coarse-grained and porphyritic homogeneous granite in the northwest corner of the body, and medium-grained, titanite-biotite-hornblende diorite that is locally migmatitic. The complex is lineated, although it is generally massive in the northern part of the body in the Nespelem quadrangle. The contact with the granite of Daisy Trail is poorly exposed but thought to be gradational. The southeast margin of the body, in the Coulee Dam 1:100,000-scale quadrangle, is cut by a gently east-dipping fault zone represented by chlorite breccia and mylonite; linear fabric in the body intensifies towards this structure. These intrusive rocks are older than Devils Elbow monzodiorite, which cuts the well-lineated granite on the shore of Franklin D. Roosevelt Lake (Atwater and Rinehart, 1984).

EPA ig_d

Granite of Daisy Trail (Eocene-Paleocene)--Ranges from leucocratic massive biotite granite, mostly in southwest part, to biotite-granitic gneiss with penetrative, generally west-northwest-trending lineation in the northeastern part of the body. The structureless, medium- to coarse-grained, but locally porphyritic, biotite granite contains equal amounts of quartz, oligoclase, and orthoclase. Metamorphic inclusions are present on the western margin. The granite closely resembles granite of Keller Butte and porphyritic granite of Coyote Creek (Holder, 1986; Atwater and Rinehart, 1984). Lineated granite in the northern part grades into and is probably the protolith of some of the muscovite-biotite gneiss in the Kettle gneiss dome (Atwater and Rinehart, 1984; Holder, 1986). The body intrudes metasedimentary rocks of the Covada Group on the east and is in fault contact with the granite and granodiorite near Meteor. The granite of Daisy Trail is associated with abundant alaskite and pegmatite dikes and is cut by dike swarms of hypabyssal dacite dikes in the western part of the body; the central part of the unit is intruded by small plugs believed to be coeval with the hypabyssal dacite dikes (Atwater and Rinehart, 1984). Emplacement of the granite of Daisy Trail was syntectonic with the formation of the Kettle metamorphic core complex (Holder, 1986). A K-Ar age from biotite is 49.9 ± 0.3 Ma; however, the granite must be older because the rock appears to have solidified before intrusion of the hypabyssal dikes dated at around 50 Ma (Atwater and Rinehart, 1984).

Pre-Tertiary Intrusive Rocks West of the Columbia River

These are generally older, heterogeneous, biotite-hornblende-bearing intrusive bodies in which K/Ar ages are likely reset. As mapped, these rocks locally include orthogneiss.

$KJia_b$

Granodiorite of Barnaby Creek (Cretaceous-Jurassic)--Small isolated intrusions into the Covada Group in the northeastern part of the Colville Indian Reservation. Hornblende is mostly altered to chlorite (Atwater and Rinehart, 1984).

KJia

Granodiorite near Gold Creek (Cretaceous-Jurassic)--Medium-grained to porphyritic hornblende-biotite granodiorite along Stepstone and Gold Creeks. Biotite-hornblende diorite is present at contacts with the metasedimentary rocks (Pzar) in the area. Small, pink to gray K-feldspar phenocrysts (0.5 to 1 cm) are euhedral to subhedral and locally exhibit Carlsbad twins. The groundmass contains clear to light-gray quartz, anhedral gray to white plagioclase, and subhedral K-feldspar. Mafic minerals are present as single mineral grains and as clots. The granodiorite contains inclusions of phyllite (Pzar); cleavage in phyllite is sharply truncated by dikes of the granodiorite. In the Gold Creek area, no preferred fabric is developed. Along Stepstone Creek a local mylonitic fabric with lineation parallel to the Okanogan gneiss dome is developed in much of the northern part of the intrusion. The fabric is truncated at the contact with the main phase of the Moses Mountain pluton ($E\text{R̶A} \, ia_{mm}$). The granodiorite intrudes metasedimentary rocks and metadiorite of North Star Creek (pKzid) (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

$KJia_m$

Granite and granodiorite near Meteor (Cretaceous-Jurassic)--Leucocratic (color index 5-20), medium-grained, equigranular to moderately porphyritic hornblende-biotite granite and granodiorite that crops out south of Twin Lakes. K-feldspar phenocrysts (<1 cm) are commonly pink; subhedral plagioclase comprises 65 percent of the total feldspar. Hornblende is sparse to moderately abundant in nonporphyritic rock; biotite locally forms pseudomorphs after hornblende. Accessory minerals include magnetite and titanite (Fullmer, 1986). The granite and granodiorite have gradational contacts, but contacts are locally abrupt. Biotite yielded a K-Ar age of 54.5 ± 0.4 Ma, but this is likely reset (Atwater and Rinehart, 1984).

$KJigd_r$

Granodiorite of Rogers Bar (Cretaceous-Jurassic)--Medium-grained, equigranular, biotite-hornblende granodiorite that contains accessory titanite and garnet (Atwater and Rinehart, 1984). The unit is intruded by aplite dikes and is strongly lineated; it intrudes the Covada Group along the Columbia River near the mouth of Wilmont Creek. A K-Ar age on hornblende is 71.1 ± 2.0 Ma, but this is probably reset (Atwater and Rinehart, 1984).

KJid

Diorite of Stepstone Creek--Fine- to medium-grained, equigranular, pyroxene-hornblende-biotite diorite and monzodiorite. The unit is similar to the granodiorite near Gold Creek and may be early phase of that intrusion (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989). Staatz (1984), however, suggests that the diorite underwent regional greenschist metamorphism and therefore may be older than the granodiorite near Gold Creek (KJia) that contains inclusions of phyllite. Subhedral, zoned (An_{40-57}) plagioclase makes up 40 to 85 percent of the rock, and orthoclase is rare. Anhedral hornblende and chlorite (after biotite and hornblende) make up 5 to 52 percent. Small anhedral quartz constitutes 3 to 5 percent of the rock. Accessory minerals include titanite, ilmenite, and apatite, as well as lesser amounts of calcite, magnetite, epidote, zircon, pyrite, hematite, clinozoisite, muscovite, and tourmaline (Staatz, 1964). The unit is cut by biotite-hornblende hypabyssal dacite dikes along the margin of the Long Lake fault. Penetrative mylonitic fabric with a trend similar to that of the Okanogan gneiss dome is well developed in the northwest corner of the diorite body (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

Tertiary and Older Intrusive Rocks East of the Columbia River

TKia

Dikes and sills (Teriary-Cretaceous)--Small bodies of granophyre and quartz porphyry; most bodies too small to show at map scale. The unit is generally restricted to the southeast corner of the quadrangle.

$TKia_h$

Intrusive rocks in the Huckleberry Range (Tertiary-Cretaceous)--Leucocratic, porphyritic biotite granite to granodiorite which locally has a fine- to medium-grained, equigranular border phase. The rock consists of 35 percent zoned, subhedral plagioclase (An_{33}); 26 to 38 percent orthoclase, including pink and white phenocrysts; 18 to 27 percent anhedral quartz; and 6 percent brown biotite. Accessory minerals include hornblende, titanite, zircon, apatite, epidote, augite, sericite, tourmaline, rutile, and calcite (Abrams; 1980; Janzen, 1981; Smith, 1982). Mafic minerals in the equigranular border phase increase to as much as 20 percent hornblende at the country rock contact (Smith, 1982). The intrusive rocks are cut by numerous aplite and alaskite pegmatite dikes. West of Wellington Peak, metasedimentary rocks at the contact with the intrusive are hornfelsed; carbonate rocks are recrystallized and silicified; quartzite and phyllite are recrystallized and foliated; and the Ledbetter Slate is bleached (Abrams, 1980; Smith, 1982).

Kia

Porphyry near Owl Creek (Cretaceous)--Bimodal, fine-grained and medium- to coarse-grained to pegmatitic monzogranite characterized by phenocrysts and clots of phenocrysts of quartz and K-feldspar in a finer grained matrix of quartz, K-feldspar, and plagioclase. The unit contains 20 to 40 percent anhedral to subhedral, gray quartz as phenocrysts and as finer grains in the matrix. Chalky white, perthitic K-feldspar makes up 20 to 35 percent of the rock as phenocrysts and in the matrix. Subhedral, fine-grained to porphyritic plagioclase (An_{16-25}), generally with albite twinning and myrmekite at contacts with K-feldspar, makes up 25 to 35 percent of the rock. Porphyritic and fine-grained, anhedral to shredded black biotite and chlorite make up 3 to 5 percent of the rock. Accessory minerals comprise 1 to 2 percent and include apatite, epidote, clinozoisite, allanite, hornblende, zircon, muscovite, titanite, and opaque minerals. The porphyry is cut by alaskite pegmatite dikes (Du, 1979). The mineralogy is similar to that of the equigranular intrusive near the Germania mine (Kig), and the porphyry may be the chilled margin and border phase of that pluton.

Kig

Equigranular intrusive rocks near the Germania mine (Cretaceous)--Yellowish-gray, fine- to coarse-grained, massive, equigranular to porphyritic monzogranite that crops out in several bodies in the southeastern part of the map area. (Rock south of O Ko Pak-Em Creek may represent a discrete pluton.) The monzogranite contains 35 to 45 percent anhedral, brownish quartz; 18 to 25 percent anhedral, perthitic and twinned K-feldspar; 24 to 37 percent plagioclase (An_{27-35}) with vermicular myrmekite along the rims of phenocrysts; and 5 to 8 percent anhedral biotite which is moderately altered to chlorite and epidote. Accessory minerals include magnetite, apatite, muscovite, hornblende, and titanite. The pluton intrudes the Togo Formation with sharp contacts and hosts tungsten and molybdenum mineralization at the Germanin mine (Becraft and Weis, 1963; Du, 1979).

Kigd

Granodiorite near Fruitland (Cretaceous)--Leucocratic, medium- to coarse-grained, equigranular to porphyritic hornblende-biotite granodiorite. Hornblende is euhedral; biotite is subhedral to euhedral and has minor chlorite alteration. The hornblende to biotite ratio is 1:10. K-feldspar phenocrysts are white. Accessory minerals include magnetite and titanite. The granodiorite contains elongate inclusions of schist and quartz-rich schist 2 to 15 cm in length. It intrudes rocks of the Covada Group, imposing a wide metamorphic halo; it is cut by hypabyssal hornblende-biotite (± pyroxene) dacite dikes (Eida) west of Enterprise Valley.

Kia_m

Pluton near the Midnite Mine (Cretaceous)--Leucocratic, medium- to coarse-grained, massive, pinkish-gray to pinkish-greenish-gray, porphyritic monzogranite and granite (Kinart, 1980). The rock contains 26 to 32 percent K-feldspar; 20 to 42 percent quartz, locally as phenocrysts; 26 to 32 percent plagioclase; and 0 to 3 percent biotite, which is partly replaced by chlorite and muscovite (Castor and others, 1982). K-feldspar, followed by quartz and plagioclase, are the dominant phenocryst compositions (Kinart, 1980). Quartz is anhedral and smoky. Subhedral to euhedral plagioclase is twinned. Muscovite (<4%) is present as inclusions in K-feldspar or as an alteration product of biotite associated with chlorite (Kinart, 1980). Accessory minerals include magnetite, apatite, fluorite, garnet, zircon, and monazite. Average U_3O_8 content is 19 ppm; the range is from 1 to 46 ppm. Strong argillic alteration is present locally (Castor and others, 1982). A U-Pb age from zircon of 75 Ma is reported by Ludwig and others (1980); Asmerom and others (1988) reported a Rb-Sr isotopic age of 74.7 ± 3 Ma from samples of this unit taken in the Coulee Dam 1:100,000-scale quadrangle.

Pre-Cretaceous Mafic Intrusive Rocks

$pKigb_b$

Ultramafic and mafic bodies near Bridge Creek (Atwater and Rinehart, 1984) (Pre-Cretaceous)--Talc-carbonate rock, greenstone, and minor serpentinite and tuff.

> "Much of the greenstone may have originated as diabase and gabbro because it commonly preserves laths of plagioclase and a subophitic texture. Possibly the Bridge Creek represents oceanic crust and mantle on which adjacent parts of the Covada Group accumulated; alternatively, the Bridge Creek and the Covada were brought together tectonically from widely separated areas" (Atwater and Rinehart, 1984, p.12).

The body is cut by hypabyssal dacite dikes (Eida) (Atwater and Rinehart, 1984).

pKigb$_s$

Mafic intrusive rocks near Stranger Creek (pre-Cretaceous)--Small body of massive, equigranular, coarse-grained, generally homogeneous hornblende-gabbro; highly varied near the contact with metamorphic rocks at northeastern margin. The unit is exposed east-southeast of Twin Lakes. It locally contains abundant fresh, unaltered, randomly oriented inclusions of metamorphic rocks along the southwestern margin (Atwater and Rinehart, 1984).

pKid

Metadiorite of North Star Creek (pre-Cretaceous)--Several small bodies of dark-green, fine- to coarse-grained diorite to gabbro that intrude the argillite (Pzar) along North Star and King Creeks and near Central Peak. The bodies contain 7 to 35 percent plagioclase (andesine, An_{33-44}) and as much as 5 percent quartz. Mafic minerals are mainly hornblende (to 88 %) and/or chlorite. Clinozoisite and epidote are locally abundant; the unit also contains minor amounts of calcite, biotite, magnetite, sericite, titanite, pyrite, and pyrrhotite. The metadiorite is schistose to structureless and locally altered and contains abundant biotite where intruded by the younger granodiorite near Gold Creek (KJia) (Staatz, 1964).

u

Serpentinite near Parmenter Creek (Mesozoic-Paleozoic)--Lenticular talc-magnesite and serpentine bodies that generally are present adjacent to the Long Lake fault. This light green-gray to gray, slickensided talc-magnesite rock has numerous weathered-out magnesite pits. The serpentine contains 55 to 75 percent talc, 25 to 40 percent magnesite, and less than 5 percent magnetite. Dark greenish-black serpentine contains antigorite and lesser amounts of magnetite, chrysotile, anthophyllite, chlorite, and picotite. A small body of serpentinite on the West Fork of the Sanpoil River (too small to show on Plate I) contains equal parts of olivine, antigorite, and less than 2 percent chrysotile, chromite, magnetite, and pyrrhotite. Serpentine intrudes argillite (Pzar) and quartzite (Pzw) and is intruded by the hypabyssal dacite dikes (Eida). Serpentinized dunite on the West Fork led Staatz (1964) to suggest that these rocks were probably all originally dunites.

Oig$_b$

Gabbro (Ordovician?)--Sill-like lenses and dikes of coarse-grained, sheared, weakly foliated, green hornblende gabbro and greenstone that intrude the Covada Group east of the Columbia River and near Twin Lakes (Smith, 1989; Fullmer, 1986; Atwater and Rinehart, 1984). Emplacement of the sills may only slightly postdate extrusion of the greenstone in the Covada Group; the gabbro predates the main phase of deformation and metamorphism. A single geochemical analysis indicates that the gabbro east of the Columbia River roughly resembles the basaltic greenstone in the Covada Group (Smith, 1989).

Zib

Intrusive greenstone dikes and sills (Precambrian Z)--Greenstone dikes that intrude Precambrian rocks below the Huckleberry greenstone; most abundant at level of the Edna Dolomite. The rock is chloritized and contains minor epidote; locally it is schistose and serpentinized (Campbell and Loofbourow, 1962).

Metamorphic Rocks

Rocks West of the Sherman Fault

og_d

Gneiss and mylonitic rocks near Deerhorn Creek--Dark-colored, medium-grained, mylonitic, hornblende-orthoclase-biotite-quartz-plagioclase schist to gneiss that separates the light-colored Moses Mountain granite and porphyritic granite of Coyote Creek from the amphibolite (pTam) along the West Fork Sanpoil River (Atwater and Rinehart, 1984). The gneiss is foliated and has only minor linear fabric; it is banded and displays layers of variously deformed pegmatite (Atwater and Rinehart, 1984). The trend of the pegmatite is roughly parallel to that of the foliation; the foliation is concordant with the contact with the porphyritic granite of Coyote Creek (EPA ig_c). Atwater and Rinehart (1984) postulated that the unit is of sedimentary origin; inclusions of phyllitic wall rock, similar to that observed in the granodiorite near Gold Creek (KJia), could be interpreted as evidence for an igneous parent (R. W. Holder and G. M. Holder, Southern Georgia College, written commun., 1989).

pTam

Amphibolite (pre-Tertiary)--Dark-green, fine- to coarse-grained greenstone to amphibolite that contains 40 to 85 percent hornblende, 15 to 55 percent unzoned plagioclase ($An_{40\text{-}55}$), and 1 to 4 percent quartz and minor titanite, limonite, apatite, orthoclase, biotite, chlorite, augite, and calcite. The amphibolite crops out on the west side of the West Fork of the Sanpoil River. The unit is apparently conformably overlain by the wacke and quartzite (Pzw) on the east according to Staatz (1964) and is intruded by Moses Mountain granite to the west (Atwater and Rinehart, 1984).

$pTsc_w$

Schist (pre-Tertiary)--Schist, phyllite, and quartzite. The upper 700 m of the unit contains thick interbeds of green calcareous, chlorite-rich or hornblende-rich schist. The schist includes fine-grained, light-gray quartzite and thin-bedded phyllite. The phyllite contains quartz, biotite, sericite, and less than 1 percent tourmaline. The unit exhibits foliation of biotite and ilmenite; quartz is sutured. The schist is present west of the Long Lake fault in the northwest part of the map area. These rocks could be upgraded Permian Anarchist Group or lower Paleozoic Covada Group. The unit is more than 1,859 m thick and generally in fault contact with the metasedimentary rocks (Pzmm) (Staatz,1964).

Pzhm

Metamorphic rocks (Paleozoic?)--Thin- to thick-bedded, light- to dark-gray quartz-mica schist in the drainages of North Star and Parmenter Creeks. The schist contains quartz, sericite, chlorite, and biotite and less than 1 percent tourmaline, pyrite, zircon, apatite, garnet, magnetite, hematite, titanite, and epidote; andalusite makes up as much as 10 percent of the rock (Staatz, 1964)

Metamorphic Rocks of the Kettle Metamorphic Core Complex

Hall Creek Gneiss

Well-lineated, amphibolite-grade paragneiss and orthogneiss are present in the lower plate of the Kettle gneiss dome. The gneiss exposed north of Twin Lakes in the Nespelem quadrangle is part of a gneissic terrane that extends north into Canada and is approximately 125 km long and 30 km wide. The central part of the metamorphic core complex is an asymmetrical antiform. The western limb is steeply dipping, the axis of the dome is nearly horizontal, and the eastern limb has a shallow east dip. The gneiss is separated from greenschist-facies rocks on the upper plate on the east limb by the narrow, low-angle, east-dipping Kettle River fault zone, which is a zone of cataclasis. Mylonite and/or chlorite breccia crops out in the fault at Ellen Lake (directly to the north in the Republic 1:100,000-scale quadrangle). The west side of the dome is intruded by syntectonic intrusive rocks such as the granite of Daisy Trail and post-tectonic intrusive rocks (Fox and Wilson, 1989).

pTsc, pTqz, pTmg, og, pThm

Hall Creek Gneiss (pre-Tertiary)--The Hall Creek Gneiss is divided into five subunits on Plate I.

pTsc

Quartzite and schist--Thick-bedded, strongly foliated muscovite schist interlayered with thick-bedded to massive quartzite that contains small shreds of sillimanite accompanied by rounded aggregates of tourmaline, elongate quartz grains, and small inclusions of zircon (Fullmer, 1986).

pTqz

Quartzite--Rusty brown, thick-bedded to massive quartzite that contains 95 to 99 percent anhedral to subhedral, elongate, fine-grained quartz and minor sillimanite. The contact with the overlying schist (pTsc) is gradational; the quartzite is in sharp contact with underlying orthogneiss(Fullmer, 1986).

pTmg

Mafic gneiss--Biotite- and hornblende-bearing gneiss located near Johns Mountain; includes marble (Atwater and Rinehart, 1984).

og

Granitic orthogneiss--Homogeneous, strongly foliated, medium- to coarse-grained, biotite (± muscovite) orthogneiss that is gradational with and possibly has a protolith of the syntectonic granite of Daisy Trail, as well as older intrusive rocks (Atwater and Rinehart, 1984). The unit includes biotite gneiss in a small area between Onion and Barnaby Creeks; the protolith there may have been the granodiorite of Barnaby Creek or the granite and granodiorite near Meteor (Atwater and Rinehart, 1984). Rocks of granitic composition in the Kettle metamorphic core complex consist of mylonitic gneiss in the central part, grading upward and outward into blastomylonite, mylonite, and ultramylonite (Fox and Wilson, 1989). Southeastern exposures of the orthogneiss are made up of 55 percent plagioclase, 25 percent quartz, 10 percent orthoclase, and 5 to 10 percent biotite and muscovite. The orthogneiss is cut by nearly concordant pegmatite dikes; orthogneiss dikes intrude the quartzite (pTqz) (Fullmer, 1986).

pThm

Heterogenous metamorphic rocks--Biotite schist and quartzite, locally interlayered with biotite (± muscovite) granitic gneiss.

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

Sample loc.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (millions of years)	Reference
				Hypabyssal dikes				
1	FM 82681-2	Hypabyssal dacite dike	Eida	48°15.95', 118°41.07'	K-Ar	hornblende biotite	38.0±0.4 46.7±0.4	Atwater and others, 1984
2	FM 91750-3	Hypabyssal dacite dike	Eida	48°27.68', 118°38.63'	K-Ar	hornblende	49.4±0.3	Atwater and others, 1984
3	FM 82980-10	Hypabyssal dacite dike	Eida	48°27.23', 118°38.04'	K-Ar	biotite	50.3±0.3	Atwater and others, 1984
4	L-7	Hypabyssal dacite dike	Eida	48°00.19', 118°23.53'	K-Ar	biotite hornblende	49.2±0.3 53.8±3.1	B. F. Atwater, USGS, written commun., 1987
5	FM 9480-1	Intrusive rhyolite near West Fork	Eir	48°28.03', 118°42.47'	K-Ar	biotite	49.5±0.3	Atwater and others, 1984
				Eocene Volcanic Rocks				
6	FM 8480-1	Sanpoil Volcanics	Evd$_s$	48°25.61', 118°43.47'	K-Ar	biotite	48.5±0.3	Atwater and others, 1984
7	78KF28L-3	Sanpoil Volcanics	Evt$_s$	48°13.99', 118°40.17'	K-Ar	biotite	50.3±0.4	Atwater and others, 1984
8	N-93	Sanpoil Volcanics, rhyodacite of Cub Hill	Ev$_s$	48°14.05', 118°58.28'	K-Ar	biotite	48.9±1.2	B. F. Atwater, USGS, written commun., 1987
				Herron Creek Suite				
9	FM 91780-2	Granite of Deadhorse Creek	Eig$_{dh}$	48°16.43', 118°41.65'	K-Ar	biotite	49.6±0.3	Atwater and others, 1984

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

Sample loc.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (millions of years)	Reference
10	837-12E	Granodiorite of Joe Moses Creek	$Eigd_j$	48°05.50', 118°46.23'	K-Ar	biotite	49.7±0.4	B. F. Atwater, USGS, written commun., 1987
				Devils Elbow Suite				
11	N51G	Devils Elbow monzodiorite	$Eimd_d$	48°09.99', 118°46.08'	K-Ar	biotite	49.6±1.2	Atwater and others, 1984
12	FM 91780-1	Devils Elbow monzodiorite	$Eimd_d$	48°16.28', 118°42.50'	K-Ar	biotite	49.9±0.3	Atwater and others, 1984
13	MHS-1-60	Devils Elbow monzodiorite	$Eimd_d$	48°17', 118°43'	Pb-Alpha	zircon	80±10	Engels and others, 1976
14	RWH-54453	Kettle Crest pluton	$Eimd_k$	48°8.61', 118°32.37'	K-Ar	biotite hornblende	45.2±1.1 47.7±1.2	Atwater and others, 1984
				Keller Butte Suite				
15	N-99	Porphyritic granodiorite of Manila Creek	EP ia_m	48°12.85', 118°58.28'	K-Ar	biotite hornblende	44.1±1.1 47.3±1.2	B. F. Atwater, USGS, written commun., 1987
16	Keller	Altered granite on Meadow Creek	EP ia_{mc}	48°03.58', 118°41.53'	K-Ar	feldspar	51.2±1.8	Armstrong and others, 1982
17	A56471	Quartz porphyry of Mount Tolman	EP ig_{mt}	48°03.39', 118°42.20' (drill core)	K-Ar	sericite	55.7±2.0	Atwater and others, 1984
18	A56470	Quartz porphyry of Mount Tolman	EP ig_{mt}	48°03.24', 118°42.20' (drill core)	K-Ar	muscovite	57.7±2.1	Atwater and others, 1984
19	A65679	Granite of Swawilla Basin	EP ia_s	48°00.47', 118°48.43'	K-Ar	biotite	58.8±2.2	Atwater and others, 1984

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

Sample loc.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (millions of years)	Reference
20	RWHNE 985C	Granite of Daisy Trail	EP ig_d	48°15.00', 118°31.57'	K-Ar	biotite	49.9±0.3	Atwater and others, 1984
				Older Intrusive Rocks				
21	E-51B	Granite and granodiorite near Meteor	$KJia_m$	48°15.32', 118°22.52'	K-Ar	biotite	54.5±0.4	Atwater and others, 1984
22	G-225A	Granite and granodiorite near Meteor	$KJia_m$	48°14.78', 118°13.19'	K-Ar	biotite hornblende	61.3±1.5 110±3	B. F. Atwater, USGS, written commun., 1987
23	E-52B	Granodiorite of Rogers Bar	KJigd,	48°03.51', 118°17.54'	K-Ar	hornblende	71.1±2.0	Atwater and others, 1984

Decay constants for K-Ar dates: $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mol/mol; $\lambda_{\beta} = 4.962 \times 10^{-10} yr^{-1}$; $\lambda_{\epsilon} + \lambda_{\epsilon'} = 0.581 \times 10^{-10} yr^{-1}$

Nespelem quadrangle, geologic map:

The stippled pattern indicates areas where Eocene hypabyssal dacite dikes constitute more than 10 percent of the rock. The dikes are also indicated by the pattern. See unit Eida in the text for details.