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

Compiled by

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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES

OPEN FILE REPORT 90-13

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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
Art Stearns - Supervisor

Division of Geology and Earth Resources
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GEOLOGIC MAP OF THE COLVILLE 1:100,000 QUADRANGLE, WASHINGTON-IDAHO

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INTRODUCTION

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

Literature review and preliminary compilation of the Colville quadrangle began in 1985. Between 1985 and 1989, reconnaissance and detailed 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 during that time through a DGER graduate student mapping program. Figures 2a and 2b show sources of geologic map data used for compilation of the Colville quadrangle map.

Age assignments of geologic units in the Colville 1:100,000-scale quadrangle were made following the flow chart in Figure 3. The geologic time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador, 1985) was used, with slight modifications of the Eocene-Oligocene and Pliocene-Pleistocene boundaries (Armentrout and others, 1983; Prothero and Armentrout, 1985; Montanari and others, 1985; Aguirre and Pasini, 1985). All known radiometric ages from the Colville quadrangle are listed in Table 1. A listing of data for selected fossil localities in the Colville quadrangle is presented in Table 2. Both tables follow the list of cited references.

Modal analyses and the International Union of Geological Sciences rock classification (Streckeisen, 1973) were used to assign plutonic rock names. Whole-rock geochemical data and the total alkali-silica (TAS) diagram (Zanettin, 1984) were the basis for assigning names to volcanic rocks.

A mixture of formal, informal, and unnamed geologic units is shown on the map (Plate 1). 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 granodiorite of Yocum Lake is Cretaceous intrusive granodiorite and is shown with the symbol $Kigd_y$.

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.

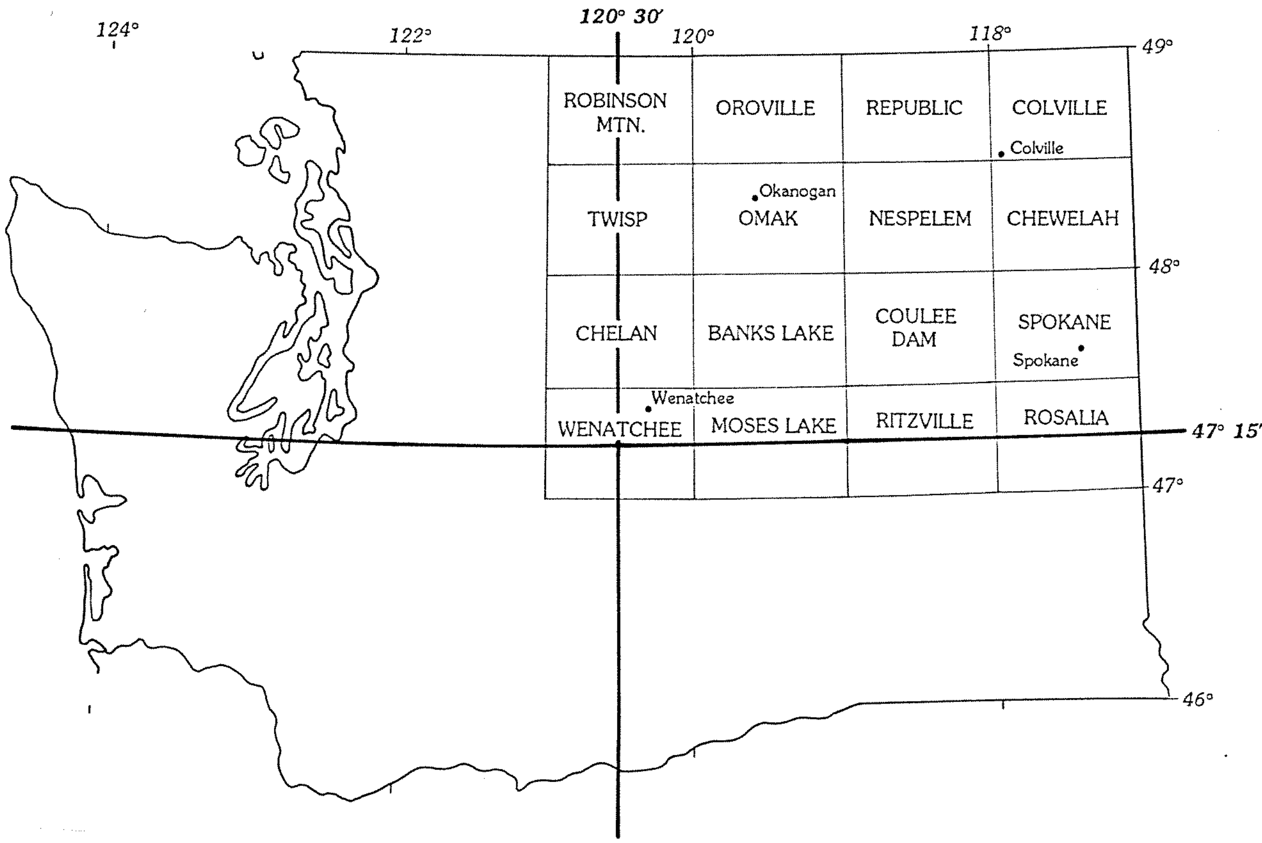

Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Sources of Map Data

Explanation for Figures 2a, 2b (facing page and following)

1. Aadland, R. K., and others, 1979, scale 1:250,000
2. Bradshaw, H. E., 1964, 2 plates, scale 1:27,500
3. Brainard, R. C., 1982, 1 plate, scale 1:40,000
4. Burmester, R. F.; Miller, F. K., 1983, 1 plate, scale 1:48,000
5. Castor, S. B., and others, 1982, plate 22, scale 1:62,500
6. Dings, M. G. ; Whitebread, D. H., 1965, plate 1, scale 1:24,000
7. Duncan, G. W., 1982, 2 plates, scale 1:62,500
8. Gager, B. R., 1982, scale 1:35,500, plate B
9. Greenman, C., 1976, 2 plates, scales 1:12,000, 1:2,750
10. Groffman, L. H., 1986, 1 plate, scale 1:24,000
11. Hogge, C. E., 1982, 2 plates, scale 1:36,000
12. Kiver, E., Stradling, D., 1987, 4 plates, scale 1:24,000
13. Laskowski, E. R., 1982, 1 plate, scale 1:24,000
14. Lindsey, K. A., 1988, 1 plate, scale 1:24,000
15. Miller, F. K., 1983, 1 plate, scale 1:48,000
16. Miller, F. K., 1988, USGS, written commun., 1:24,000
17. Miller, F. K., 1988, USGS, written commun., 1:48,000
18. Miller, F. K.; Frisken, J. G., 1984, 1 plate, scale 1:100,000
19. Miller, F. K.; Yates, R. G. 1976, scale 1:125,000
20. Mills, J. W., and others, 1985, scale 1:24,000.
21. O'Keefe, M. E., 1980, plate, scale 1:24,000.
22. Park, C. F., Jr.; Cannon, R. S., Jr., 1943, plate 1, scale 1:96,000
23. Phillips, W. M., 1979, 1 plate, scale 1:24,000
24. Roback, R. C., 1990, written commun., scale 1:24,000
25. Schuster, J. E., 1988, DGER, written commun., scale 1:24,000
26. Thorsen, G. W., 1966, 1 plate, scale 1:63,360
27. Todd, S. G., 1973, Figure 2, scale 1:84,480
28. Yates, R. G., 1964, scale 1:31,680
29. Yates, R. G., 1971, scale 1:31,680
30. Yates, R. G., 1976, scale 1:31,680
31. Yates, R. G., 1986, USGS (retired), written commun., scale 1:24,000

ERRATUM

Page 2 of Open File Report 90-13, the explanation for Figures 2a and 2b, Number 28 should read Yates, R. G., 1976, scale 1:31,680 and Number 29 should read Yates, R. G., 1971, scale 1:31,680.

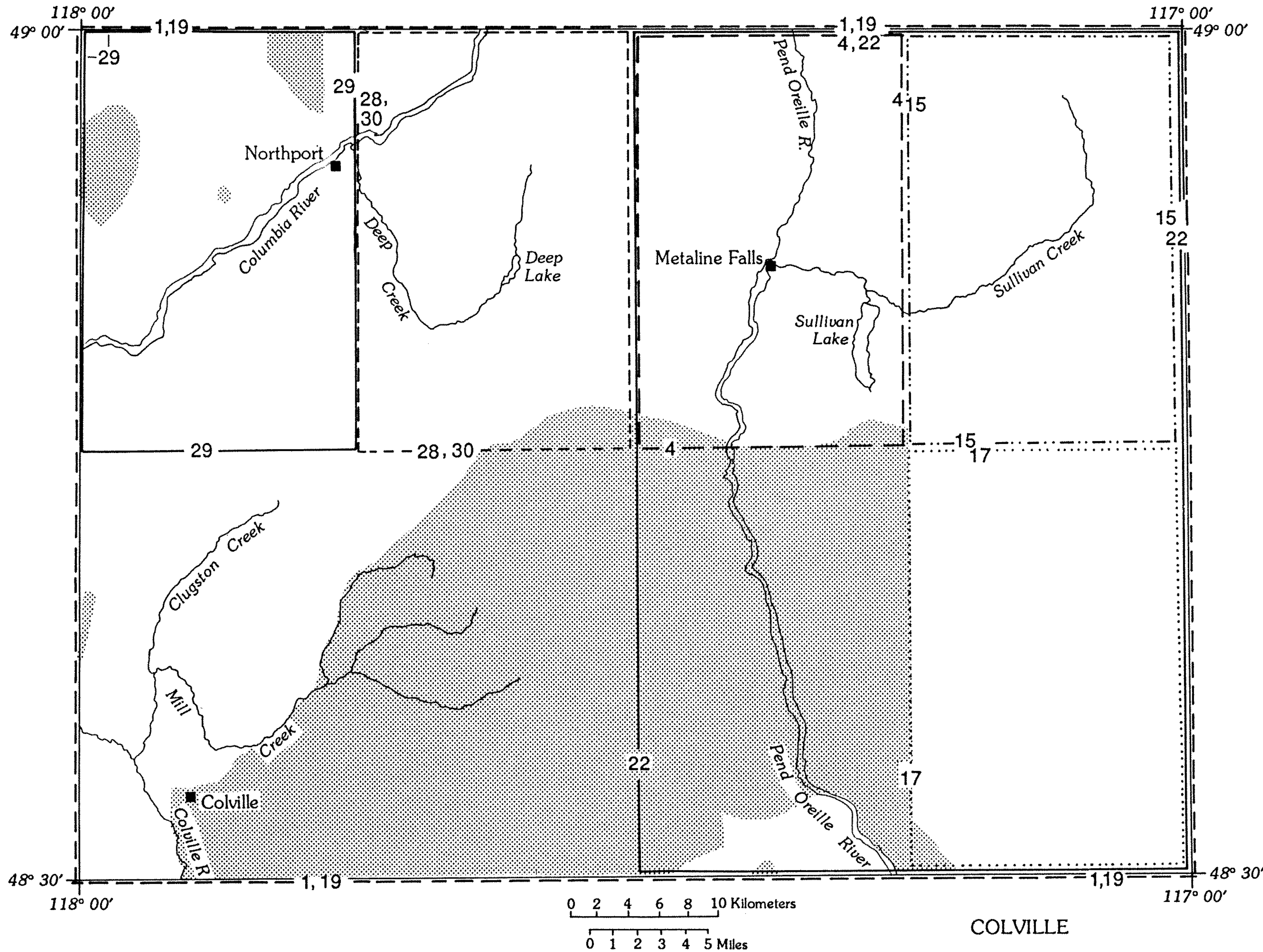

Figure 2a. Sketch map showing the primary sources of geologic quadrangle mapping used to compile the Colville 1:100,000-scale geologic map. Stippled areas show supplemental DGER mapping.

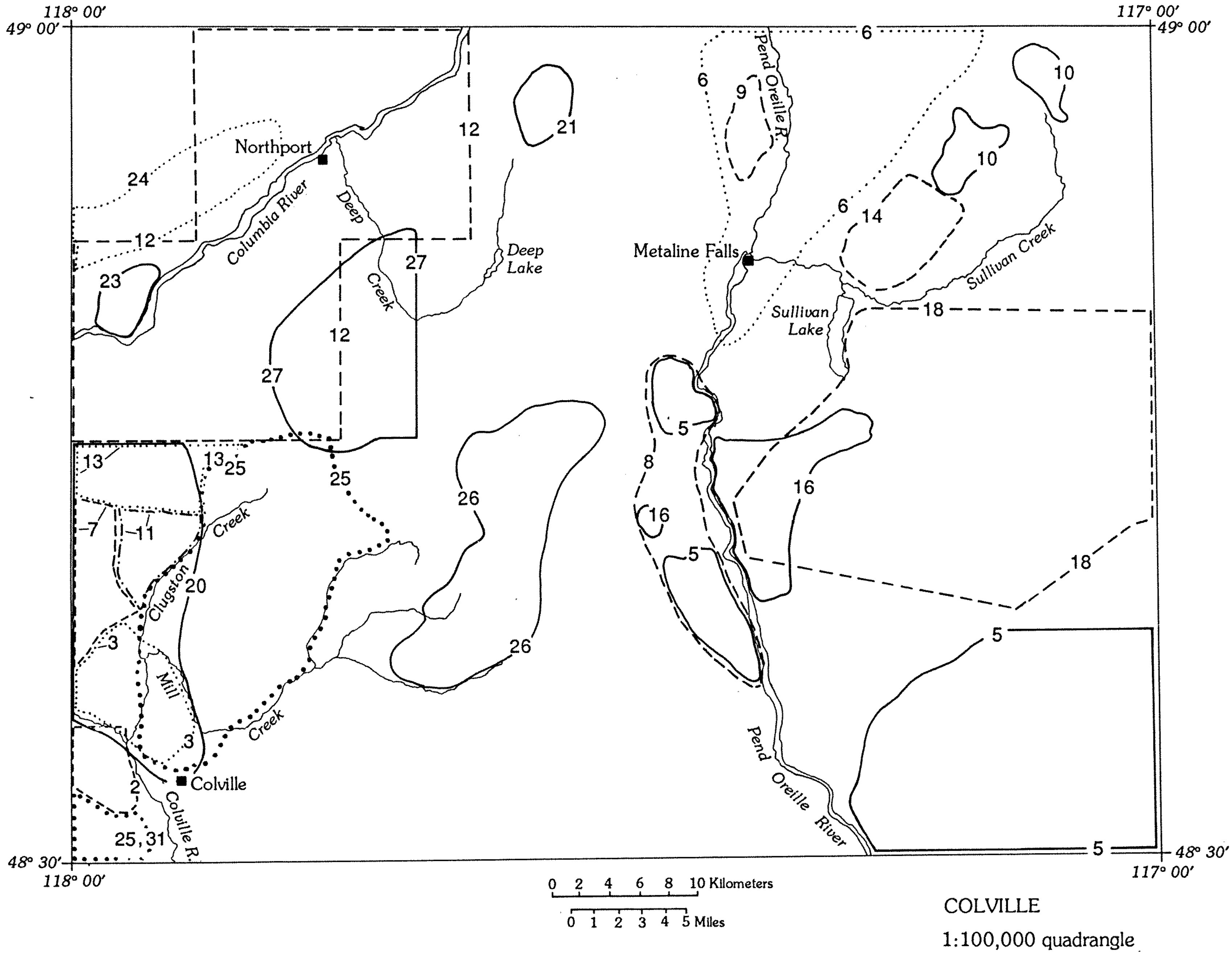

Figure 2b. Sketch map showing other sources of geologic mapping used to compile the Colville 1:100,000-scale geologic map.

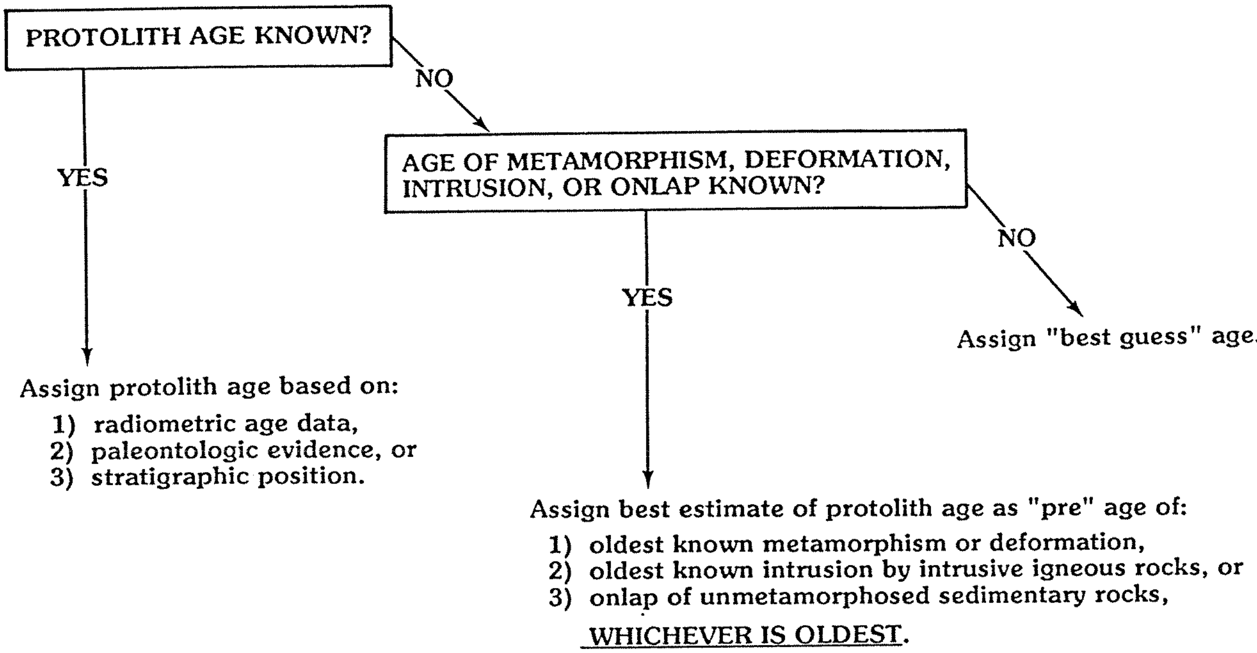

Figure 3. Flow chart for age assignment of geologic units, Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description includes information on how the age of the unit was determined.

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

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

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

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

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

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

I thank all the geologists who have previously worked in or near the area of the Colville quadrangle and whose excellent work has laid the foundation for understanding the complex geology of the area.

R. G. Yates (retired USGS), Gerald Thorsen (retired DGER), and J. E. Schuster (DGER) all generously provided unpublished mapping and words of wisdom. R C. Roback (Univ. of Texas, Austin), K. A. Lindsey (Washington State Univ.), and M. T. Smith (Univ. of Arizona) provided new information and ideas from their recent dissertation work. Trygve Höy and Kathryn Andrew (British Columbia Ministry of Energy, Mines, and Petroleum Resources) shared new information through discussions and field trips in the Rossland Group. A. G. Harris (USGS) provided timely identification of the conodonts. P. R. Jackson (Teck Resources Inc.) provided additional unpublished conodont data. W. M. Phillips and H. W. Schasse (both DGER) aided in mapping and collection of conodont samples. Claire Carter (USGS) provided preprints of her publications. E. P. Kiver and D. F. Stradling (both Eastern Washington Univ.) shared their new Quaternary mapping. J. A. Morton (Resource Finance Inc.) added additional information on the Metaline Mining District. S. Z. Waggoner and K. L. Stoffel (both DGER) provided lively discussions and information about regional geology. J. E. Schuster drafted the final map. I especially thank F. K. Miller (USGS) for graciously sharing unpublished mapping and new ideas and for his thorough review of a draft of the manuscript. The map and manuscript were reviewed by J. E. Schuster, W. M. Phillips, E. P. Kiver, J. A. Morton, R. C. Roback, and F. K. Miller. Final copy was ably prepared by N. A. Eberle and J. R. Snider (both DGER).

GEOLOGIC SETTING

Geologic units in the Colville 1:100,000-scale quadrangle can be divided into three pre-Cretaceous geologic blocks: (1) Precambrian Y to Silurian miogeosynclinal rocks deposited in shelf to continental slope settings; (2) Ordovician(?) to Triassic eugeosynclinal metasedimentary rocks deposited on outer shelf to continental slope areas; and (3) Permian to middle Jurassic eugeosynclinal metasedimentary and metavolcanic rocks which are part of the Quesnellia terrane (Figs. 4 and 5). Precambrian rocks in block 1 outline the edge of the Cordilleran miogeosyncline after a late Precambrian rifting event. Metasedimentary and metavolcanic rocks in block 2 were probably deposited in extensional basins west of the Cordilleran miogeosyncline, and are in part similar to deposits formed in fault-bounded basins in the Cordillera from Nevada to the Yukon. The Early to Middle Jurassic Rossland Group metavolcanic rocks, in block 3, probably record arc volcanism as subduction waned prior to plate collision, possibly involving the accretion of Quesnellia. Pre-Middle Jurassic rocks have been affected by deformation associated with the Kootenay arc, a 400-km-long, westward-younging belt characterized in Washington by northeast-trending, refolded folds that have penetrative axial planar cleavage. The contact between the miogeosynclinal and eugeosynclinal rocks is a thrust fault parallel or subparallel to the axis of regional (F_1) tight to isoclinal folds. Miogeosynclinal metasedimentary rocks were intruded by biotite-, hornblende-biotite-, and muscovite-biotite-bearing intrusive bodies of Upper Cretaceous age (~100 Ma), which were not affected by deformation associated with the Kootenay arc. A regional Eocene thermal event resulted in the formation of: amphibolite-grade metamorphic core complexes (in the Republic 1:100,000-scale quadrangle); intrusive granitic bodies and dikes; local fault-bounded volcanic and sedimentary rock-filled basins; and top-to-the-east movement on the listric, normal Newport fault on the east side of the quadrangle.

Explanation for Figure 4 (facing page)

Evs	Eocene volcanic and sedimentary rocks
J	Jurassic (Rossland Group; includes Upper Cretaceous Sophie Mountain Conglomerate
P	Permian metasedimentary rocks
T	Triassic metasedimentary rocks
CO	Carboniferous-Ordovician metasedimentary and metavolcanic rocks
S-C	Silurian through uppermost Proterozoic miogeoclinal rocks
Z	Windermere Group
Y_{pr}	Priest River Group
Y_b	Belt Supergroup
m	High-grade metamorphic rocks
Ei	Eocene intrusive rocks
Ki	Cretaceous (hornblende)-biotite granitic rocks
Kiat	Cretaceous muscovite-biotite granitic rocks
u	Ultrabasic rocks
	normal fault
	thrust fault
	reverse fault

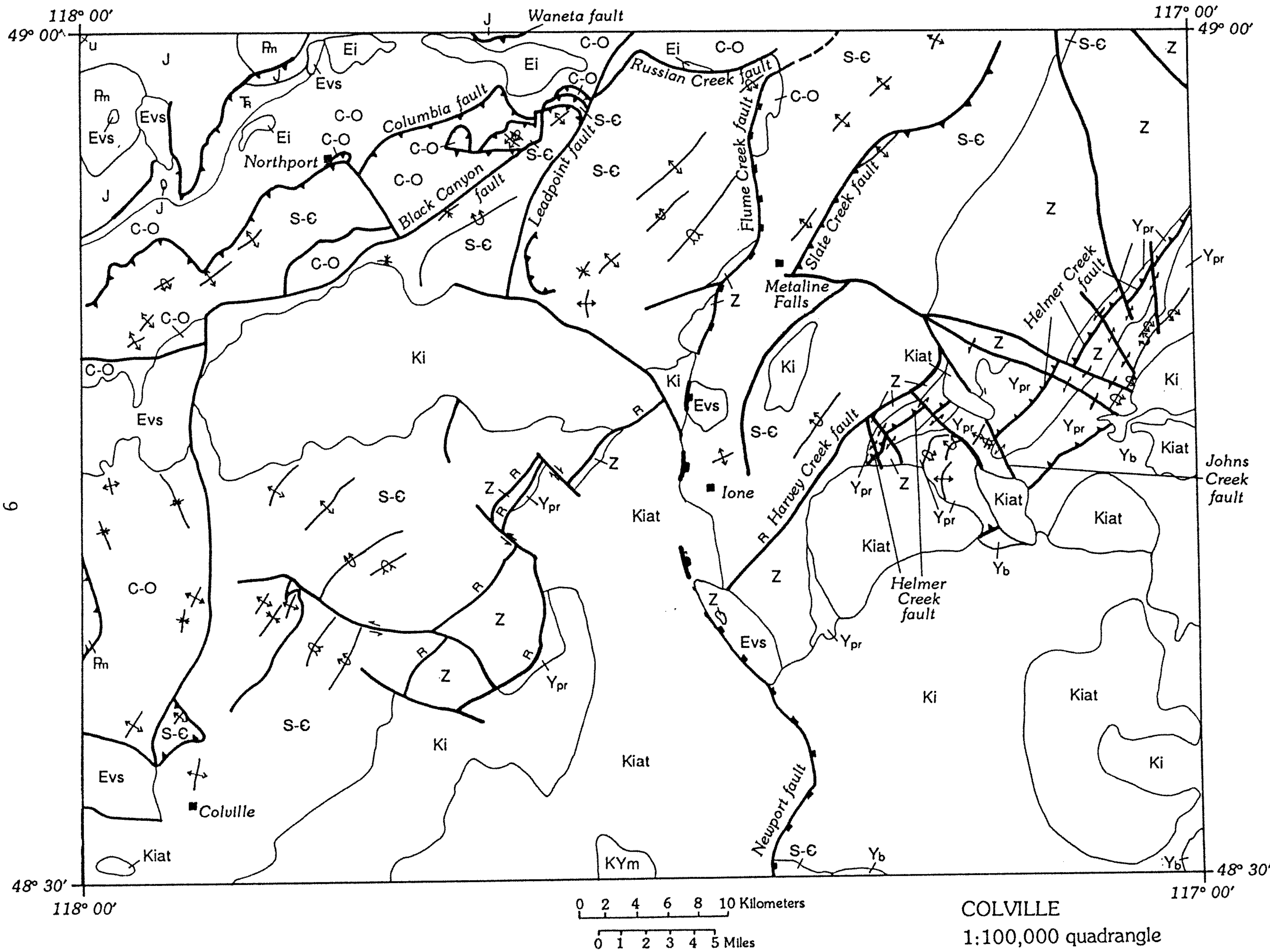

Figure 4. Major tectonic and structural features of the Colville 1:100,000-scale quadrangle.

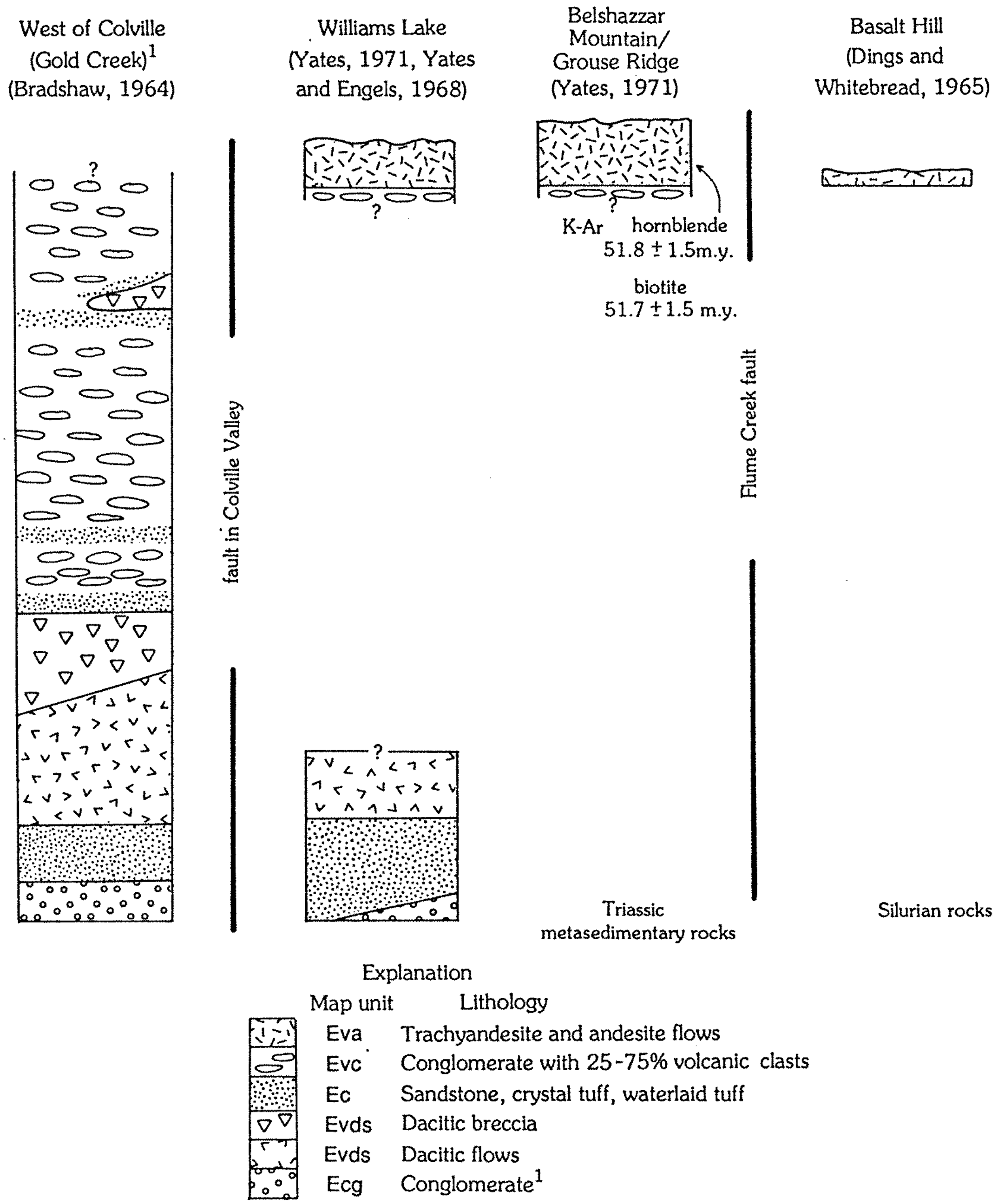

Figure 5. Schematic diagram of the stratigraphy and possible correlation of Eocene sedimentary and volcanic rocks. The section in the Colville area is approximately 3,050 m thick (Bradshaw, 1964).

DESCRIPTION OF MAP UNITS

Sedimentary and Volcanic Deposits and Rocks

Quaternary Sedimentary Deposits

Nonglacial Deposits

Qa

Alluvium (Holocene)--Silt, sand, and gravel in stream beds, floodplains, and terraces, and stratified sand and gravel in alluvial fans; locally includes eolian and lacustrine deposits.

Qls

Landslide deposits (Holocene to Pleistocene)--Chiefly slides of unconsolidated glaciolacustrine deposits (Qgl) associated with rounded and glacially polished bedrock, perched water tables, and areas along the Columbia River undercut by waves. Some slides may be related to fluctuations in the water level in F. D. Roosevelt Lake (Kiver and Stradling, 1986).

Glacial Deposits

Qgd

Glacial drift (Pleistocene)--Stratified and unstratified deposits of clay, silt, sand, gravel, and boulders deposited directly by glacial ice or by water emanating from glacial ice; includes outwash, till, and glaciolacustrine deposits.

Qgo

Outwash (Pleistocene)--Massive to crudely bedded, poorly sorted, fine to coarse sand, rounded to well-rounded gravel, and silt with local inclusion of clay. This unit is differentiated on the map from other drift only along the Columbia River. Small boulders were deposited locally along the northern part of the river in the quadrangle close to a late ice front; small cobbles are present to the south near Kettle Falls, west of Colville. Kame terraces are composed of low-energy deposits of sand, silt, and clay; coarse sand and gravel are present in areas formerly adjacent to stagnant ice (Kiver and Stradling, 1986). The unit disconformably overlies glaciolacustrine deposits (Doak, 1986) and is overlain by eolian sands (not shown).

At the time of maximum glaciation during the late Wisconsin, the western part of the map area was completely covered by glaciers. Stages of deglaciation are shown by the kame terraces at an elevation of 525 m, as well as by terraces at 536 m and 487 m. Terrace levels below 487 m may indicate levels of glacial Lake Columbia or may be local ice-contact surfaces. Ice overran a bedrock divide on the east side of the Columbia River and created narrow valleys that later became sites of spillovers for ice-marginal streams and lakes. Meltwater flowed south through Swede Pass, Williams Lake, and Phalen Lake, and into the Echo Valley to the Colville Valley. Kame terraces on east side of State Route 251 near Boundary and on the west bank of Big Sheep Creek (secs. 23-26, T. 40 N., R. 39 E.) indicate areas of ice stagnation (Kiver and Stradling, 1986).

Qgt

Till (Pleistocene)--Poorly sorted, crudely stratified cobbles in a matrix of clay and silt exposed in the Columbia River valley. The unit reflects a fluctuating ice front or re-advance of ice (Doak, 1986).

Qgl

Glaciolacustrine deposits (Pleistocene)--Deposits of fine sediment mapped in the Columbia and Pend Oreille River valleys; elsewhere included with Quaternary glacial drift. In the Columbia River valley the unit consists of finely horizontally to wavy laminated, very fine sand, silt, and clay interlaminated with light-gray to light-brown-gray silt. These sediments were deposited in glacial Lake Columbia during the last glacial advance and contain calcium carbonate-cemented concretions (Doak, 1986). Glacial Lake Columbia terraces at elevations of 475-490 m, 430-455 m, and 402-415 m of Kiver and Stradling (1982) are exposed along the Columbia River (Kiver and Stradling, 1986; Doak, 1986). In the Pend Oreille River valley the unit includes buff-colored silt, fine sand, and gravel that displays slump features. Highest terraces there reach an elevation of 785 m; a lower terrace is at 640 m. The unit locally interfingers with glaciofluvial deposits (Park and Cannon, 1943).

Tertiary Sedimentary and Volcanic Rocks

Eocene volcanic and sedimentary rocks are present in the Williams Lake area (north-northeast of Colville), near Gold Creek (west of Colville), on Belshazzar Mountain (west of Northport), on Grouse Ridge (north of Northport), along the Pend Oreille River, and on Basalt Hill (north of Metaline Falls). These rocks are the extrusive products of a major thermal event associated with regional extension throughout northeastern Washington and southern British Columbia during the early and middle Eocene. The greatest volume of Eocene volcanic rocks is in the Republic and Toroda Creek grabens to the west in the Republic 1:100,000-scale quadrangle.

Some of these Eocene rocks (specifically dacite near Williams Lake and Gold Creek [Evd_s] and conglomerate and tuffaceous sandstone near Williams Lake [Ecg_o, Ec_o]) have been correlated with the Sanpoil Volcanics and the O'Brien Creek Formation, respectively, which were described by Muessig (1967) in the Republic graben. (See also Yates, 1971; Pearson and Obradovich, 1977.) Other units (such as andesite flows [Eva] on Belshazzar Mountain, Grouse Ridge, and on Basalt Hill; the Tiger Formation [Ecg_t]; the volcanic conglomerate [Evc] on Belshazzar Mountain, Grouse Ridge, and near Williams Lake [Evc]) have been tentatively correlated with the Sanpoil Volcanics or the overlying Klondike Mountain Formation by various authors (Yates, 1971; Pearson and Obradovich, 1977).

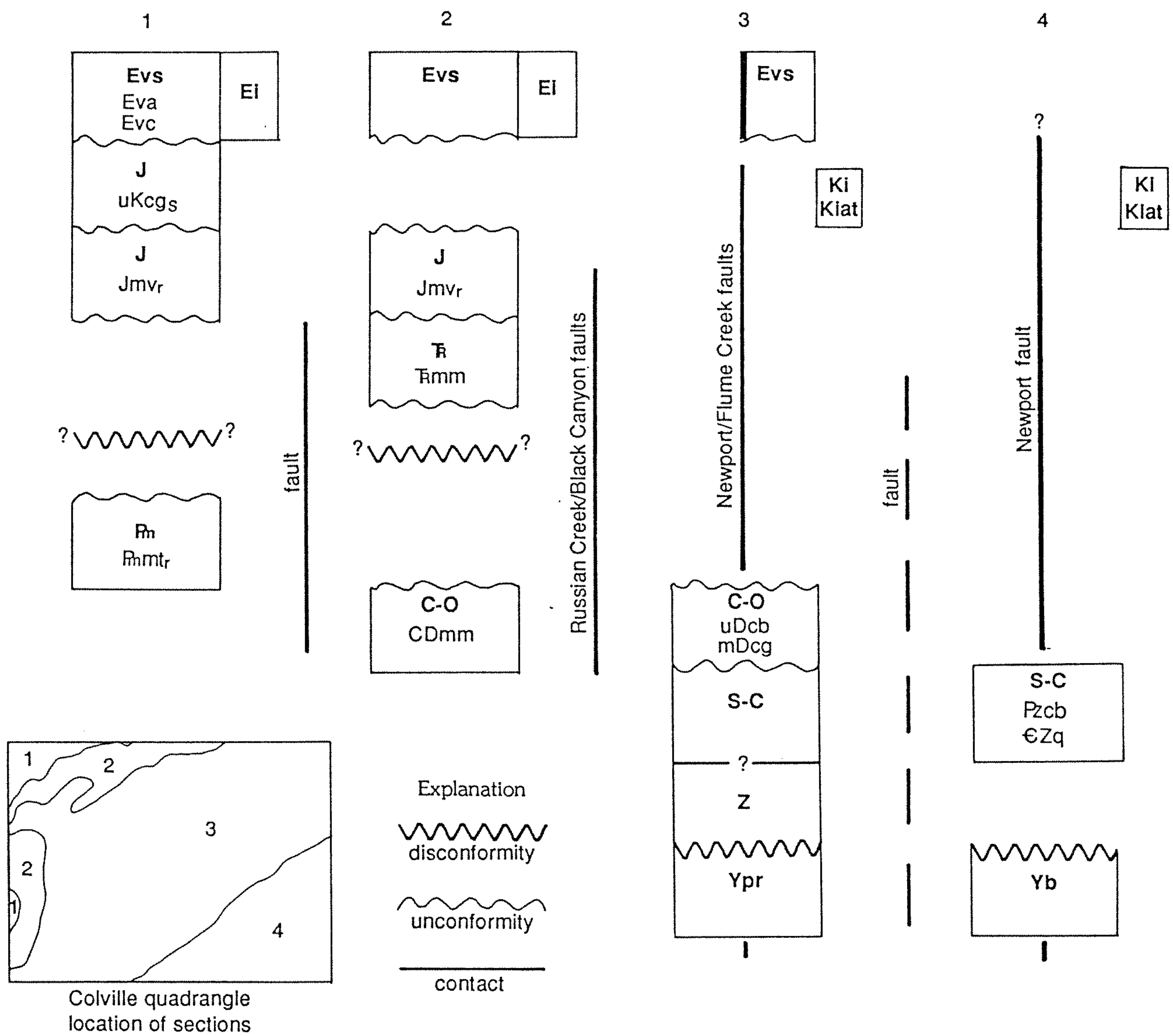

Figure 6. Schematic stratigraphic sections. Refer to the explanation on tectonic and structure map (Fig. 4) for lithologic symbols shown in bold. Symbols shown below the bold symbols refer to rock names on the geologic map and map explanation (Plate 1) and in the text. These names are shown where it is significant that only some rock units of the broad time-stratigraphic units shown on the tectonic map are actually present. Sections 1 and 2 depict the relations of the Rossland Group to both the Upper Triassic and Permian-Pennsylvanian metasedimentary rocks. Sections 3 and 4 depict the lack of Windermere (Z)- aged rocks above the Belt Supergroup rocks, whereas the Windermere Group rocks overlie rocks of the Priest River Group.

A diagram of the stratigraphy and possible correlation of the Eocene rocks in the Colville quadrangle is presented in Figure 6. Regional correlation of Eocene volcanic and sedimentary rocks is complicated by their geographic isolation, facies variations on a local scale, and poor stratigraphic and geochemical control of these rocks in both the Colville and the Republic 1:100,000-scale quadrangles.

Pearson and Obradovich (1977) suggested that Eocene volcanic and sedimentary rocks originally covered a large area of northeastern Washington and now are preserved only in fault-bounded grabens. However, it is more likely that deposition was restricted to structurally controlled extensional basins containing local volcanic centers. Nearly east-west-trending faults on the north (inferred) and south sides of the Colville Valley between Colville and Kettle Falls appear to bound the Eocene units there. Structures controlling deposition of volcanic units on Belshazzar Mountain, on Grouse Ridge, and near Williams Lake are less evident, but are likely present. On the east side of the map, the Tiger Formation is bounded by and likely genetically related to probable listric normal faults associated with the Newport fault zone (Gager, 1982), an extensional feature (Harms, 1982). Holder and Holder (1988) suggest that, in the Republic 1:100,000-scale quadrangle, intrusion of Paleocene to Eocene intrusive rocks of the Colville batholith, gneiss-dome development, and formation of volcanic and sedimentary rock-filled grabens are broadly contemporaneous and largely of early Tertiary age.

Ecg_t

Tiger Formation (Eocene)--Nonmarine, poorly sorted, locally derived conglomerate, fanglomerate, and arkosic sandstone restricted to the Pend Oreille River valley. The thickness of unit ranges from 300 to 2,000 m; clast length ranges from 1 cm to 3 m. The formation was informally subdivided by Gager (1982) into eight members, two of which are present in the Colville 1:100,000-scale quadrangle. The Box Canyon member is dominated by poorly sorted, subangular clasts of Paleozoic black slate, phyllite, and quartzite in a sandstone matrix. The apparently overlying, but also interfingering Lost Creek member, exposed south of Tiger, is dominantly hornblende-biotite granodiorite and Precambrian Z greenstone clasts in a matrix of arkosic sandstone. The Tiger Formation in Little Muddy Creek, west of Ione, is dominated by subangular dolomite clasts. The formation unconformably overlies Precambrian and Paleozoic rocks in the Colville quadrangle. Approximately 10 km to the south of the quadrangle, east of the Pend Oreille River, the Tiger Formation unconformably overlies the Sanpoil Volcanics; apparently a considerable amount of erosion took place before deposition of the Tiger (Gager, 1982). Plant fossils (Sequoia sp., Quercus sp., Trochodendroides sp., and ?Laurus sp.) were identified by R. W. Brown (in Park and Cannon, 1943). Gager (1982) suggested a Miocene age for this unit; however, palynomorphs analyzed by A. P. Audretch (in Harms, 1982, p. 12) bracket an age range within the lower to middle Eocene. Harms (1982) suggests that these rocks occupy a stratigraphic position similar to that of the Klondike Mountain Formation. Pearson and Obradovich (1977) correlate the Tiger Formation with the lower member of the Klondike Mountain Formation. However, the true stratigraphic position of the Tiger is unconstrained.

Found on the upper plate of the Newport fault, the Tiger Formation is interpreted as a syntectonic basin-fill deposit that is genetically related to and was rotated by the Newport fault (Harms, 1982, p. 82). Gager (1982) suggests that the Tiger Formation was also cut by the last movement on the Newport fault zone.

Eva

Andesite flows (Eocene)--Medium-gray to green-gray, fine-grained to aphanitic and porphyritic andesite, trachyandesite, and basaltic andesite flows, tuff, and intrusive bodies that contain small plagioclase laths and euhedral and subhedral phenocrysts of hornblende, pyroxene, olivine, and biotite that are commonly replaced by chlorite.

The unit crops out on Belshazzar Mountain, Grouse Ridge, in the Williams Lake area, and on Basalt Hill, west of Metaline Falls. The flows on Belshazzar Mountain are commonly propylitically altered and contain quartz-, chalcedony-, and calcite-filled amygdules. On Basalt Hill the rock is dark grayish-green to black, aphanitic to fine-grained, vesicular trachyandesite containing very small crystals of clinopyroxene, olivine, and sodic plagioclase in a matrix of glass (16%), palagonite (13%), and orthoclase (12%); clinopyroxene and olivine make up nearly 33 percent of the rock. Accessory minerals include magnetite, ilmenite, apatite, biotite, and limonite. This unit is approximately 61 m thick on Basalt Hill (Dings and Whitebread, 1965) and less than 300 m thick elsewhere.

Flows are separated from pre-Tertiary rocks in the Belshazzar and Grouse Ridge areas by volcanic rock-bearing conglomerate (Evc). In the Williams Lake area andesite flows also overlie conglomerate that rests on rocks which have been correlated with the Sanpoil Volcanics (Yates, 1971). Trachyandesite on Basalt Hill rests directly on Paleozoic rocks (Dings and Whitebread, 1965). Biotite and hornblende from a probable flow on Belshazzar Mountain yielded K-Ar ages of 51.7 ± 1.5 Ma and 51.8 ± 1.5 Ma, respectively (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

The andesite flows were not correlated with the Sanpoil Volcanics by Yates and Engels (1968), but Pearson and Obradovich (1977, p. 10-11) correlated these rocks with the lower member of the Klondike Mountain Formation of Muessig (1967) in their regional correlation. The stratigraphic position of the andesite flows above rocks correlated with the Sanpoil Volcanics led Cheney (1980) to suggest that the mafic volcanic rocks are correlated with the upper member of the Klondike Mountain Formation of Muessig (1967). However, the radiometric ages from Belshazzar Mountain are older than the age considered typical for the base of the Klondike Mountain Formation (48 Ma), suggesting that the unit could be part of the Sanpoil Volcanics.

Evc

Volcanic conglomerate (Eocene)--Clast-supported, poorly sorted conglomerate containing of medium- to coarse-grained sand- to boulder-size, subangular to rounded, volcanic-rock clasts that crops out near Williams Lake, near Gold Creek, on Belshazzar Mountain, and on Grouse Ridge. This locally derived unit contains pebble-size clasts of quartzite and other Paleozoic and Mesozoic rocks and 20 to 60 percent subrounded clasts of Eocene volcanic rock (Yates, 1971) in a matrix of finer grained angular clasts of similar composition. The unit includes lenses of volcanic breccia, pebbly sandstone, and siltstone near Gold Creek; it also includes fragments of quartzite, argillite, chert-pebble conglomerate, wacke, limestone, and granitic rocks (Bradshaw, 1964). The conglomerate is more than 1,520 m thick near Gold Creek (Bradshaw, 1964), and less than 60 m thick elsewhere. It unconformably overlies Mesozoic and Paleozoic rocks on Belshazzar Mountain and Grouse Ridge and Eocene dacite flows correlated with the Sanpoil Volcanics elsewhere (Yates, 1971).

Although Pearson and Obradovich (1977, p. 19) suggest that "some of the youngest sandstone and conglomerate beds [near Colville] may be equivalent to Klondike Mountain Formation", they go on to state that because "none of the volcanic rocks characteristic of these formations [Klondike Mountain Formation] [are] known in the Kettle Falls area, all but the lower prevolcanic [Ecg_o] conglomerate is considered a part of the Sanpoil Volcanics." Yates and Engels (1968) include the volcanic rock-bearing conglomerate with the Sanpoil Volcanics.

Evd_{sb}, Evd_s

Sanpoil Volcanics (Eocene)--Dacite and andesite in the Williams Lake area were originally called the Phalen Lake volcanics by Weaver (1920), and were later mapped by Yates (1971) who correlated them with the Sanpoil Volcanics in the Republic graben (Muessig, 1967). Volcanic rocks west of Colville near Gold Creek were originally named the Palmer Volcanics by Weaver (1920, p. 103) and later mapped as such by Bradshaw (1964). Pearson and Obradovich (1977, p. 18) found that these rocks in the Colville area were petrographically indistinguishable from the Sanpoil Volcanics and "should be correlated with them. The name Palmer Volcanics is preempted and should not be adopted..." Flows within the Sanpoil Volcanics were identified by Pearson and Obradovich (1977) and Yates (1971) as rhyodacite. These rocks plot as dacite and andesite on a TAS diagram which uses whole-rock geochemistry (Zanettin, 1984) and is used in this report as the source of volcanic rock names.

Evd_{sb}

Sanpoil Volcanics, breccia (Eocene)--Volcanic breccia and conglomerate, pyroclastic flows, and indurated mud flows that outcrop west of Colville. The breccia is composed of 95 percent rounded to subangular clasts of gray porphyritic augite dacite flow rock, which is texturally and petrographically similar to dacite stratigraphically below it. The matrix is tuffaceous at some localities. Fragments range from less than 2 cm to 2 m in diameter, but average about 4 cm; beds range from 10 cm to more than 100 m in thickness. Large boulders are more common near the base of the unit; the breccia is well sorted near Gold Creek. This unit is approximately 274 to 305 m thick (Bradshaw, 1964). Bradshaw (1964) suggested it was deposited as lahars and pyroclastic breccia.

Evd_s

Sanpoil Volcanics, flow rock (Eocene)--Medium-gray, porphyritic augite-biotite, augite-hornblende-biotite, hornblende-biotite, and augite-biotite-hypersthene dacite and andesite flows that crop out west of Colville near Gold Creek and near Williams Lake; includes some intrusive rock. The thickness is estimated to be 274 m at Gold Creek, near Colville (Bradshaw, 1964).

In the Colville area, gray dacite and andesite is flow banded, in part fragmental, and interbedded with minor sedimentary and pyroclastic rocks. Approximately 40 percent of the dacite is composed of fine-grained anhedral quartz and subhedral feldspar (mostly oligoclase), and interstitial magnetite, augite, plagioclase, apatite, ferromagnesian minerals, and chlorite. Phenocrysts consist of: hornblende and euhedral biotite (as much as 55%); white, equant, twinned and zoned plagioclase (An_{38-46}) (35-40%); augite; and hypersthene. Quartz phenocrysts are rare (Bradshaw, 1964). Hornblende and pyroxene commonly form porphyritic aggregates and twinned rosettes. Chlorite forms psuedomorphs after minor hypersthene; augite is generally fresh. Accessory minerals include magnetite (1-2%), apatite, and zircon.

A K-Ar age on hornblende from Williams Lake area is 51.1 ± 1.5 Ma (Yates and Engels, 1968; recalculated using current IUGS standards, Steiger and Jaeger, 1977). A K-Ar biotite age of 50.2 ± 1.3 Ma was obtained from rocks west of Gold Creek in the Republic 1:100,000-scale quadrangle (Pearson and Obradovich, 1977).

Ec_o

O'Brien Creek Formation (Eocene)--Water-laid, reworked, feldspathic crystalline tuff, crystalline tuff, and tuffaceous sandstone in the Williams Lake area and west of Colville near Gold Creek. Reworked, feldspathic crystalline tuff contains euhedral biotite, quartz, and plagioclase. Coal seams are present in the Williams Lake area (Yates, 1971). The unit is approximately 100 m thick, overlain by the Sanpoil Volcanics, and cut by shonkinite dikes (Eik) (Yates and Engels, 1968).

West of Colville near Gold Creek, 150 m of sandstone at the base of the section is overlain by 24 m of pyroclastic and reworked vitric tuff, lapilli tuff, and crystalline tuff (Bradshaw, 1964).

Biotite from this unit yielded K-Ar ages of 41.6 ± 1.2 Ma and 40.2 ± 1.3 Ma in the Williams Lake area. However, these ages are thought to be too young, possibly because of argon leakage due to ground-water circulation (Yates and Engels, 1968). Biotite in shonkinite that cuts the tuff in the Williams Lake area yielded a K-Ar age of 51.0 ± 1.5 Ma (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

Ecg_o

O'Brien Creek Formation, conglomerate (Eocene)--Nonvolcanic conglomerate with locally derived clasts. The unit is present west of Colville and near Williams Lake. In the Williams Lake area most of the unit is thought by Yates (1971) to be megabreccia derived from the Spirit pluton. There, the unit is overlain by water-laid tuffaceous sandstone and cut by shonkinite (Eik) and hypabyssal dikes (Eida) (Yates, 1971). Yates (1971) describes the conglomerate as a distinct unit, stratigraphically below the O'Brien Creek Formation, but it is correlated with the O'Brien Creek Formation by Pearson and Obradovich (1977, p. 19).

Near Gold Creek this unit is mapped as the lower conglomerate by Bradshaw (1964) and contains rounded to subangular clasts of quartzite, argillite, chert-pebble conglomerate, wacke, limestone, and granitic rock in a yellowish-brown sandstone matrix which includes coarse-grained to pebble-size angular fragments of argillite. The unit is estimated to be 183 m thick. A thin tuff is present at the top of the conglomerate (Bradshaw, 1964). Correlation of the section near Gold Creek with the O'Brien Creek Formation is uncertain; however, Pearson and Obradovich (1977, p. 18) suggest that "the older nonvolcanic conglomerate may be in part a time equivalent of the O'Brien Creek Formation."

Mesozoic Sedimentary Rocks

$uKcg_s$

Sophie Mountain Formation (Upper Cretaceous)--Nonmarine, poorly to moderately well sorted, rounded pebble to boulder conglomerate; restricted to the area between the Kettle and Columbia Rivers and north into British Columbia. Clast size (2.5-60 cm) and type vary from one locality to another; clasts locally include purplish-red quartzite, black chert, vein quartz, greenstone, and fine-grained granite in an arenaceous matrix. Little (1982) reports clasts of the late Middle Jurassic Nelson batholith in the conglomerate in southern British Columbia. The thickness of the section exceeds 100 m; dips of 10 to 70 degrees are reported.

Mesozoic Metasedimentary and Metavolcanic Rocks

Rossland Group

This Lower Jurassic group includes basalt, basaltic andesite, and trachyandesite flows, flow breccia, tuff, and metasedimentary rocks that generally crop out between the Columbia and Kettle Rivers and continue to the north into British Columbia. In British Columbia the Rossland is divided (in descending order) into the Hall, Elise, and Archibald Formations (Yates, 1964, 1971; Höy and Andrew, 1988; Little, 1960, 1982). Rossland Group rocks in the Colville quadrangle are tentatively correlated with the Elise and Archibald Formations.

The age of the Rossland Group is based on marine macrofossils. The Elise Formation contains Sinemurian (Early Jurassic) ammonites (Arniotites sp.) in siltstone in the basal part of the formation near Trail, British Columbia. Fossils of Toarcian (late Early Jurassic) age are present in the overlying Hall Formation (Little, 1982).

Rossland Group rocks are generally in fault contact with lower Paleozoic rocks in the Colville quadrangle, but they unconformably overlie the Permian Mount Roberts Formation in Sackit Canyon in the Republic 1:100,000-scale quadrangle (Roback, 1989) and near Patterson, British Columbia (Little, 1982). The group overlies the Karnian-Norian (early Late Triassic) fine-grained, siliciclastic metasedimentary rocks containing minor limestone near Cougar Mountain and Flat Creek; the nature of the contact is uncertain, but it is probably an unconformity (R. C. Roback, Univ. of Texas, Austin, oral commun., 1989) (Fig. 5). The Rossland Group and the underlying Mount Roberts Formation are included in the Quesnellia terrane (Monger and others, 1982).

Jmv_r

Greenstone--Dark-green, fine-grained and porphyritic augite, augite-biotite, and augite-hornblende basalt, basaltic andesite, and trachyandesite flows, flow breccia, and tuff. The greenstone is dominantly volcanic breccia; coherent or massive flows and nonvolcanic clasts are rare. Interbedded gray to black siltite and conglomerate are also present (Beddoe-Stephens, 1982; Höy and Andrew, 1988; Little, 1982). Marked facies changes have been recognized in the Elise Formation in southern British Columbia (Höy and Andrew, 1990; Andrew and others, 1990).

Greenstone exhibits regional greenschist facies metamorphism; it is locally strongly schistose or sheared. Augite is commonly partially or completely altered to an assemblage of actinolite, biotite, epidote, and chlorite (Höy and Andrew, 1988), and hornblende is replaced by secondary biotite and calcite (Beddoe-Stephens, 1982). Phenocrysts are set in a fine-grained matrix of plagioclase, biotite, chlorite, epidote, and carbonate (Höy and Andrew, 1988).

Jmt_r

Metasedimentary and metavolcanic rocks--Greenschist, dark-gray to black, pyritic argillite and chert, wacke, limestone, and conglomerate interbedded with minor green-gray, fine-grained porphyritic flows and flow breccia; includes conglomerate interbedded with flows along Flat Creek (Yates, 1971).

Jcg_r

Conglomerate (Jurassic ?)--Limestone-, quartzite-, chert-, and wacke-bearing conglomerate with a few beds of thin- to medium-bedded quartzite to wacke that display penecontemporaneous deformation features. This unit is generally present north of Little Sheep Creek and east of Sheep Creek. It includes carbonate mapped by Yates (1971) as being of probable Jurassic age and rocks east of Sheep Creek mapped as Sophie Mountain Formation by Yates (1971), which are most likely part of the Archibald Formation. Gray-white, fine-grained limestone, thin-bedded to massive crinoidal limestone, and dark-brown siliceous limestone are present as large blocks(?) and 1- to 7-cm-wide subrounded clasts in an arenite matrix or interbedded with black chert. Conodonts from a limestone clast include Neostreptognathodus sp. indet. and Neostreptognathodus aff. N. tschuvashovi Kozur - N. svalbardensis Szaniawski. The fossils indicate a middle to late Leonardian (late Early Permian) age for the clast (A. G. Harris, USGS, written commun., 1988), suggesting that it is probably a metacarbonate clast from the Mount Roberts Formation. Chert-pebble conglomerate and intraformational breccia containing angular to subrounded clasts of graded wacke, fossiliferous limestone, and chert in a quartz arenite to wacke matrix are present down-section(?) from the fossil locality. Depending on interpretation of the structure, the unit could be in excess of 400 m thick. Andrew and others (1990) report 300 m of graded, pebble-bearing sandstone and 430 m of chaotic matrix-supported conglomerate and pebble sandstone with approximately 10 percent limestone and sandstone clasts near the top of the Archibald Formation; some of these limestone clasts are reported to contain Permian fossils.

Upper Triassic Metasedimentary Rocks

A new fossil collection has identified the first occurrence of Upper Triassic metasedimentary rocks in the Colville quadrangle. Late Triassic conodonts were collected (R. C. Roback, Univ. of Texas, Austin, written commun., 1989) and identified (A. G. Harris, USGS, written commun., 1989) from metacarbonate rocks interbedded with siliciclastic rocks from the upper(?) part of the Flagstaff Mountain sequence of Yates (1971) in the northwestern part of the quadrangle (Table 2). The Flagstaff Mountain sequence was originally given a Carboniferous(?) age by Yates (1971); Devonian conodonts were later identified by G. D. Webster (Beka, 1980; Adekoya, 1983) from the Flagstaff Mountain sequence near Flagstaff Mountain and Ansaldo Lake (Table 2). The lithology of rocks containing Devonian and Triassic fossils is similar, contact relations are not known, and the actual extent of Triassic rocks is uncertain.

₮cb

Carbonate rocks--White to black, thin-bedded to massive, fine- to medium-grained limestone and dolomite interbedded with argillite, phyllite, and argillaceous limestone; commonly recrystallized and containing as much as 20 percent combined fine-grained quartz, chlorite, sericite, plagioclase, and carbonaceous matter. The unit was originally mapped as part of the Flagstaff Mountain sequence by Yates (1971) and was thought to be Carboniferous(?) in age. More recently, early Late Triassic (Karnian-Norian) conodonts have been identified from three localities near the contact with Rossland Group rocks (A. G. Harris, USGS, written commun., 1989). Neogondolella was identified near Cougar Mountain. Neogondolella polygnathiformis (Budurov and Stefanov) and Neogondolella cf. N. polygnathiformis (A. G. Harris, USGS, written commun.,1989) were collected by R. C. Roback (Univ. of Texas, Austin, written commun., 1989) from a site 6 m south of the jeep trail in sec. 17, T. 39 N., R. 38 E.; they indicate a Late Triassic age. Neogondolella polygnathiformis (Budurov and Stefanov) was identified (A. G. Harris, USGS, written commun., 1989) from a limestone with considerable fossil hash that was collected from a roadcut 60 m south of the U.S. National Forest boundary in sec. 1, T. 39 N., R. 38 E. (Table 2). A limestone with fossil hash and Devonian conodonts (identified by G. D. Webster, Washington State Univ. in Beka, 1980) is included in this unit because of its proximity to carbonate rocks with similar lithology that contain Upper Triassic fossils.

₸ mm

Metasedimentary rocks--Gray to black, argillaceous limestone, and gray phyllite with minor interbeds of gray quartzite. This unit includes part of unit Ds_6 of Beka (1980) and part of unit Cf_3 of Yates (1971). Rocks are mapped as Triassic where they are in contact with limestone that contains Upper Triassic conodonts or where rocks of the Flagstaff Mountain sequence were mapped by Yates (1971) in stratigraphic contact with the Rossland Group rocks. As mapped here, it may include Carboniferous-Devonian metasedimentary rocks. The extent of unit and contact relations are poorly understood--rocks with Devonian fossils could be in conformable, unconformable, or structural contact with the Upper Triassic rocks. Rocks with Late Triassic fossils on the Colville quadrangle may correlate with the Slocan Group in southeastern British Columbia, which unconformably overlies upper Paleozoic rocks there (Klepacki, 1985).

Paleozoic Metasedimentary and Metavolcanic Rocks

Pmm_r

Mount Roberts Formation (Permian)--Thin- to thick-bedded, poorly sorted, light- to medium-gray, lithic arenite and wacke with lesser amounts of dark-gray to black siltstone; light-gray to cream, massive to medium-bedded, chert-bearing, fossiliferous limestone, and sandy limestone; tuffaceous metasedimentary rocks; chert-pebble conglomerate; pebble to boulder conglomerate; and minor interbedded metavolcanic flows and crystalline tuff (Yates, 1971; Roback, 1989; Little, 1982). Different lithologic types generally interfinger and are commonly discontinuous. The unit locally displays normal and reverse grading, rhythmic bedding, and scour and slump structures (Roback, 1989).

Poorly sorted, angular to subangular, coarse- to very coarse grained, lithic arenite contains 14 to 40 percent quartz, 17 to 48 percent feldspar, and 39 to 60 percent lithic rock fragments (Roback, 1989). It also contains monocrystalline quartz with perfect doubly terminated crystals or crystals that have rounded corners and embayments interpreted by R. C. Roback (Univ. of Texas, Austin, written commun., 1990) as being of volcanic origin. Feldspars are dominantly plagioclase (Roback, 1989), although Little (1982) reports 15 percent K-feldspar in similar rocks in Canada. Feldspar is typically altered to white mica and/or replaced by carbonate. Lithic rock fragments include clasts of foliated and nonfoliated argillite, siltstone, sandstone, chert, and volcanic rocks. The composition of framework grains in the lithic rock fragments is very similar to that of the host lithology. Some clasts of fine-grained metasedimentary rocks show pressure solution cleavage with random orientations, indicating that the cleavage formed prior to resedimentation. Siliceous clasts include chert, argillaceous chert, cherty argillite, microcrystalline quartz aggregates, and radiolarian and spicule-rich chert. Mafic volcanic rock fragments are in equal proportion to quartz-feldspar-bearing fragments; fragments of plutonic rocks, carbonate rock, stretched quartzite, mica schist, and grit are also present (Roback, 1989).

Little (1982, p. 12) suggested that foraminifera collected near Paterson, immediately north of the international border, most likely indicated a Pennsylvanian age; however, the fauna did not rule out a Permian age. Limestone on the north side of Sackit Canyon in the Republic 1:100,000-scale quadrangle has yielded abundant Permian macrofossils (Roback, 1989). These same limestones have also yielded late Early Permian conodonts (A. G. Harris, USGS, written commun., 1988).

The thickness is estimated at 600-1,200 m in Canada (Little, 1982) and 0-120 m to the west in the Republic 1:100,000-scale quadrangle (Bowman, 1950). Contacts with the Rossland Group in the Colville quadrangle are generally covered, intruded by Coryell dikes, or faulted. Little (1982) reports that the contact with the Rossland Group in British Columbia near the international border is a sinuous unconformity. Roback (1989) has identified an angular unconformity with the Rossland Group in Sackit Canyon in the Republic 1:100,000-scale quadrangle.

Pmm

Argillite near Kettle Falls (Permian)--Light- to dark-gray, brown-weathering, fossiliferous, siliceous, and calcareous argillite and fine- to medium-grained wacke with scattered pods of fossiliferous limestone (Pcb) that crops out 12 km northwest of Colville. Mills (1985) reports that a specimen of fine-grained, calcareous argillite typically contains 65 percent calcite and 35 percent chalcedony, and minor clay and sulfide minerals. Fossils in the argillite include: brachiopods, pelecypods, gastropods, scaphopods, crinoid stems, and plant parts. On the basis of the fossil assemblage in the argillite and the limestone pods (Pcb), Mills and Davis (1962) concluded that the deposition of the unit began in the late Leonardian (late Early Permian) and continued into the early Guadalupian (Middle Permian). The argillite is in fault contact with Carboniferous-Ordovician greenstone (COmv) (Mills, 1985) and is correlated with the Mount Roberts Formation by R. C. Roback (Univ. of Texas, Austin, written commun., 1990).

Pcb

Carbonate near Kettle Falls (Permian)--Light- to dark-gray, thin-bedded to massive limestone that forms pods 60-800 m long in the argillite near Kettle Falls. The pods contain fusulinids, tetracorals, bryozoans, gastropods, and crinoid stems (Mills and Davis, 1962). Limestone pods in the Republic 1:100,000-scale quadrangle contain fusulinids (Pseudofusulinella stevensi, Schwagerina missionensis, and Parafusulina antimonioensis) that indicate a Permian age (West, 1976). A limestone lens located in the Colville quadrangle has faunal and lithologic characteristics that differ from those of the other limestones studied by West (1976) directly to the west in the Republic 1:100,000-scale quadrangle; this lens contains several species of Psuedoendothyra, ostracods, and abundant pellets, including pellets and organic material covered with blue-green algae of the "Osagia"-type forming concentric laminated coatings, which were not observed in the other limestone pods studied. In addition, bryozoans common in the other limestone pods in the unit were not observed. The occurrence of species of Psuedoendothyra suggests a possible Pennsylvanian age for this lens (West, 1976). The carbonate near Kettle Falls has been correlated with the Mount Roberts Formation by R. C. Roback (Univ. of Texas, Austin, written commun., 1990).

Carboniferous-Devonian(?) Metasedimentary and Metavolcanic Rocks

CDmm, CDmv, CDcb

Dark-colored, generally fine-grained, siliciclastic, quartz ± chert-dominated rocks with subordinate carbonate and metavolcanic rocks are exposed in the western half of the Colville quadrangle and are commonly referred to as the "black shale belt" (Fig. 4). These rocks are present along the Columbia River, between the Columbia River and the Kettle River, on Stone Mountain, in Echo Valley, on Red Top Mountain, and possibly north of Russian Creek.

East and west of the Columbia River in the northwest part of the map area, these rocks were mapped by Yates (1971) in structural blocks which include the Flagstaff Mountain, the Pend d'Oreille [sic], and the Grass Mountain sequences. Yates (1971) correlated these rocks and suggested a Carboniferous(?) age. Conodonts of Givetian and Famennian age were subsequently identified in limestone pods in the Flagstaff Mountain sequence, indicating a Middle to Late Devonian age for the part of the section containing the fossils (Beka, 1980; Adekoya, 1983). In the Pend d'Oreille [sic] sequence on the west side of the Columbia River across from Northport and geographically separated from the main part of that sequence (Yates, 1971), a late Devonian conodont (Palmatolepis sp.) was identified by G. D. Webster (Beka, 1980). North of the international border leiorhynchid brachipods were collected by Little (1982) from rocks contiguous with the Pend d'Oreille [sic] sequence. The rocks in British Columbia were designated as Carboniferous because of the Devonian to Permian range of the fossils, and the previous designation of Carboniferous(?) by Yates (1964, 1971) for similar rocks in the Colville 1:100,000-scale quadrangle.

Quartz- and chert-bearing arenite and wacke, basaltic greenstone, argillaceous rocks, and limestone are present in the Echo Valley area and are similar in part to the rocks mapped by Yates (1964, 1971). These rocks have been designated as Carboniferous-Ordovician because (1) one locality yielded a Devonian conodont, (2) there are similarities between these rocks and those in the Flagstaff Mountain sequence (Laskowski, 1982), and (3) good correlations have been made by M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) with similar rocks in the Nespelem 1:100,000-scale quadrangle (Joseph, in press) that have yielded Ordovician fossils.

Rocks in the "black shale belt" are everywhere in fault contact with the lower Paleozoic miogeoclinal section. Yates (1970) suggested that the miogeoclinal section is thrust over the Carboniferous-Devonian rocks in the northwestern part of the map area. Watkinson and Ellis (1987) believe that the contact is a thrust fault parallel or subparallel to the axial plane of ductile F_1 regional tight to isoclinal and overturned to recumbent folds. F_1 structures are refolded by F_2 open and upright to overturned folds.

Upper and Middle Devonian siliciclastic and carbonate rocks are exposed northwest of Metaline Falls. A limestone conglomerate with a Middle Devonian (lower Givetian) matrix and clasts containing Middle and Early Devonian fossils is in fault contact with limestone containing Late Devonian (Frasnian) stromatoporoids, bryozoa, brachiopods, and corals (Greenman and others, 1977; Table 2).

CDmm

Metasedimentary rocks--Black siliceous and carbonaceous phyllite and argillite; gray to gray-green argillite and phyllite; and subordinate gray, calcareous argillite and light-gray quartzite. The unit includes most of the Flagstaff Mountain sequence of Yates (1971), the Grass Mountain and Pend d'Oreille [sic] sequences of Yates (1964, 1971), the Lime Creek block of Yates (1964), and the argillite in Russian Creek (Yates, 1970, 1976). It also includes metacarbonate units not large enough to show at this map scale.

Argillite and phyllite contain fine- to very fine grained (1.5-0.005 mm) quartz, carbonaceous material, muscovite, biotite, chlorite, sericite, orthoclase, plagioclase, and clay. Carbonate is rare, although argillite may be calcareous where it is interbedded with limestone (CDcb); the unit locally contains as much as 25 percent carbonaceous material. Pyrite is present in places as disseminated grains; pyrrhotite and chalcopyrite are accessory minerals. Black, thin-bedded, slatey argillite locally grades into fissile black slate which contains minor beds of gray phyllite, fine- to medium-grained, thin-bedded quartzite, and gray-white limestone (Beka, 1980).

Fine-grained quartzite is medium gray and gray-green and consists of as much as 85 percent elongate quartz grains, 5 percent sericitized albite, and 9 percent orthoclase and accessory pyrite and limonite (Beka, 1980).

Carbonaceous argillite is interbedded with black limestone and massive barite-bearing limestone near the Flagstaff Mountain barite deposit. Argillite near this deposit is anomalously high in vanadium and barium; limestone and the argillite there contain barium (in celsian) (Jackson, 1986). The unit also includes a 1- to 3-m-thick conglomerate bed in calcareous argillite near the Flagstaff Mountain barite deposit (Jackson, 1986).

The fine-grained sedimentary rocks of the Grass Mountain sequence, which is centered on Stone and Red Top Mountains, are similar to the Flagstaff Mountain and Pend d'Oreille [sic] sequences of Yates (1964, 1970), but the sequence does not contain greenstone and generally lacks chlorite. On Red Top Mountain, where Yates (1976) reports the best stratigraphic section, the unit contains siliceous, thin-bedded, argillaceous material in a fine-grained matrix of sericite and quartz; it contains more than 80 percent silica, approximating chert, but it is clastic in nature (Yates, 1976). Black, poorly sorted, fine- to medium-grained quartzite is interbedded with the black slate in the lower part. Quartz is strained, and a cataclastic texture is common. The unit also contains minor recrystallized chert, albite, microcline, and muscovite.

Fossiliferous black clastic limestone crops out in Black Canyon; it was designated part of the Lime Creek Mountain block by Yates (1964). Fossils in this turbiditic limestone include Alveolites (coral) in a crinoid hash; the age range is Silurian to Devonian (Yates, 1976). Conodonts from the clastic limestone indicate a post-Silurian age, probably post-Early Devonian (A. G. Harris, USGS, written commun., 1987). All contacts are faults.

Well-bedded, black, fine-grained, carbonaceous, noncalcareous argillite is present along Russian Creek (Dings and Whitebread, 1965) and north of the international border (Fyles and Hewlett, 1959). It contains 60 percent argillaceous material and 40 percent fine- to very fine grained quartz (Yates, 1976). This unit locally grades into argillaceous sandstone with lenses of poorly bedded medium-gray limestone and dolomite. Although it was originally mapped by Dings and Whitebread (1965) as part of the Ledbetter Slate, they indicated that these rocks are lithologically different from most of what they had mapped as Ledbetter Slate elsewhere in the area; the unit is also more deformed than most of the Ledbetter. In British Columbia, a contiguous block, fault bounded on three sides, was also mapped by Little (1960) as the Active Formation (equivalent to the Ledbetter Slate). Yates (1970, 1976), however, considered these rocks to be similar to the siliceous, chert-like sediments in the Grass Mountain sequence.

Bedding has been virtually erased in most places, but, where preserved, it is parallel to S_1 and S_2. F_2 folds S_1 into small closed to open kinks; where developed to a high degree, S_2 crenulation foliation essentially erases S_1 foliation (Beka, 1980).

CDmv

Greenstone--Greenstone and green-gray chloritic phyllite of probable volcanic origin. Calcareous greenstone contains albite, chlorite, actinolite, and epidote. The clastic nature of some feldspars and mafic minerals led Beka (1980) to suggest that the rock was probably originally a pyroclastic rock. Greenstone on Flagstaff Mountain is schistose to porphyritic and contains phenocrysts of plagioclase (with albite and carlsbad twins), and hornblende which is partially replaced by chlorite and epidote. The groundmass consists of small crystals of chlorite, calcite, feldspar, and patches of epidote (Jackson, 1986).

CDcb

Carbonate rock--Thin- to thick-bedded, fine-grained, massive to thinly laminated, medium- to light-gray limestone in irregular 2- to 20-m-thick pods; contains as much as 20 percent subangular to subrounded grains of quartz, 5 to 10 percent muscovite, 5 to 10 percent carbonaceous material, and 5 to 15 percent pyrite. Calcite is stretched and forms irregular to elongate crystals; elongate pyrite lenses in limestone beds emphasize the direction of F_1 and F_2 (Beka, 1980). The unit may in part be turbidites. It is shown on the map where carbonate bodies are large enough to be mapped as a separate unit; elsewhere, it is included in CDmm or CDmt.

Conodonts were identified by G. D. Webster (in Beka, 1980; in Adekoya, 1983) from limestone interbedded with the pelitic rocks (Table 2):

South flank of Flagstaff Mountain in limestone interbedded with barite: Polygnathus costatus and Icriodus introlevatus, suggesting an early Middle Devonian age (Beka, 1980).

South flank of Flagstaff Mountain (Sells-Flagstaff Group mine, sec. 4, T. 39 N. R. 39 E.): Seven species of the Polygnathus varcus Zone (Middle and Upper varcus Subzones) and six species of the hermani-cristatus Zone; suggests a late Middle Devonian age (Adekoya, 1983).

1.2 km north of Ansaldo Lake: Palmatolepis marginifera duplicata, indicating a Late Devonian (middle Famennian) age. The limestone is highly deformed; recrystallized macrofossils, including crinoid columnals, were also present in the sample (Beka, 1980).

A limestone lens with metasedimentary and metavolcanic rocks in the Pend d'Oreille [sic] sequence of Yates (1970) on the west side of the Columbia River north of Northport: Palmatolepis sp., suggesting a Late Devonian (Famennian?) age (G. D. Webster, in Beka, 1980).

CDmt

Metasedimentary and metavolcanic rocks--Gray to gray-green phyllite and schist, with lesser metatuff, cherty argillite with interbeds and lenses of greenstone, gray calcareous phyllite, brownish-gray to gray quartzite, and gray limestone. In places, the argillite and phyllite contain as much as 15 percent each sericite and chlorite. The schist contains 50 percent chlorite, 20 percent calcite, and 30 percent quartz and albite. In thin-section, sheared and altered basaltic greenstone displays felted mats of feldspar (albite?) with phenocrysts of uralitic hornblende that have sparse unaltered cores of monoclinic pyroxene, as well as accessory chlorite, calcite, epidote, and quartz (Yates, 1976). The fine- to coarse-grained, thin- to medium-bedded quartzite contains 60 to 95 percent quartz, 5 to 40 percent muscovite, biotite, and chlorite and accessory plagioclase, microcline, apatite, zircon, limonite, and pyrite. This unit is at least 300 m thick on the north slope of Red Top Mountain (Yates, 1976).

The unit includes interlayered green and silver phyllite near Flat and Crown Creeks that likely were originally in part greenstone or tuff. These rocks are composed of quartz, muscovite, patches of chlorite, calcite, albite, and epidote (Yates, 1971; Beka, 1980). The unit serves as a markerbed that can be traced for several kilometers (Yates, 1971; R. C. Roback, Univ. of Texas, Austin, oral commun., 1989).

Carboniferous-Ordovician(?) Metasedimentary and Metavolcanic Rocks near Echo Valley

COmv, COq, COmt, COcb, COcg, COmm

Quartz- and chert-bearing arenite and wacke, basaltic greenstone, quartz-bearing argillaceous rocks, chert-pebble conglomerate, and limestone are present in Echo Valley where they are in fault contact with lower Paleozoic rocks. The area was mapped and lithologic units have been defined by Laskowski (1982), Hogge (1982), Duncan (1982), Brainard (1982), and Mills and others (1985). These rocks were originally included in the Cambrian to Carboniferous Mission Argillite by Weaver (1920). However, Mills (1985) suggests that the name Mission Argillite be dropped and that no formation designation be given to these rocks until more work has been done. Conodonts, including several species of Palmatolepis, were identified by G. D. Webster (Lasowski, 1982) and Sandberg and others (1988) as early Late Devonian (early Famennian) from a carbonate-barite-bearing lens east of the Uribe mine (Laskowski, 1982). Greenstone on Rattlesnake Mountain was called Carboniferous by Mills (1985) because it appears to be stratigraphically above a package of rocks with Upper Devonian fossils and it was faulted against metasedimentary rocks with Permian fossils. Laskowski (1982) suggested the metasedimentary rocks in Echo Valley could be correlated with part of the Flagstaff Mountain sequence of Yates (1971); both units contain limestone that yields Devonian conodonts. M. T. Smith and G. E. Gehrels (Univ. of Arizona, written commun., 1990) suggest that rocks in the Echo Valley may correlate with chert-quartz-bearing arenite enclosing lenses of chert pebble conglomerate 24 km to the southwest in the Nespelem 1:100,000-scale quadrangle (Joseph, in press), which they call the Bradeen assemblage. They also suggest that the greenstone unit (COmv) with minor interbedded quartzite in the Echo Valley area may correlate with a similar sequence of basaltic volcanic rocks in the Covada Group, also in the Nespelem quadrangle, where Ordovician macrofossils and conodonts have been recovered.

Metasedimentary and metavolcanic rocks of this unit continue to the west into the Republic 1:100,000-scale quadrangle, where they are shown as $CDmm_m$ and $CDmv_m$ (Stoffel, 1990).

COmv

Greenstone and green schist--Dark-green-gray to medium-gray, basaltic greenstone, lapilli tuff, and schist. Greenstone contains 30 to 50 percent chlorite, 20 to 30 percent plagioclase, 10 to 15 percent iron oxide, and 5 to 15 percent calcite, and accessory zeolite, hematite, and rutile. It includes flows with pillows or calcite-filled vesicles. It is intercalated with limestone (COcb) and quartzite (COq). Hogge (1982) and Laskowski (1982) note a lateral facies change from greenstone in the southern part of Echo Valley to green argillite and tuff (COmt) in the northern part. The unit is generally sheared and has a sharp contact with the wacke unit on Rattlesnake Mountain (Brainard, 1982).

COq

Quartzite--Massive, medium-grained, gray quartzite, with angular grains; interbedded with greenstone (Brainard, 1982)

COmt

Green argillite and tuff--Fine-grained, grayish-green phyllitic argillite and schist with stretched lapilli and amygdules and interbedded slate and chert-bearing wacke; contains 40 percent chlorite, 30 percent sericite, 20 percent plagioclase, and 5 percent opaque minerals, and accessory muscovite and pyrite. Hogge (1982) and Laskowski (1982) describe a lateral facies change from greenstone lavas (COmv) in the southern part of the Echo Valley to green argillite and tuff in the northern part. The unit is approximately 1,300 m thick on Rattlesnake Mountain (Brainard, 1982).

COcb

Carbonate rock--Light- to medium-gray to black, fine- to coarse-grained, thickly laminated to massive limestone, marble, and siliceous marble in pods and beds interbedded with clastic rocks and greenstone. Accessory minerals include subangular quartz grains, chlorite, sericite, plagioclase, and carbonaceous material. Lenses range in thickness from 2 m to 60 m.

Late Devonian conodonts from a 5-m-thick bed of gray, fine-grained, barite-bearing limestone intercalated with siliceous argillite 50 m east of the Uribe mine were identified by G. D. Webster. Fossils include eight species of Palmatolepis, Polygnathus sp., and Priunrodina cf. Pr. alternata (Laskowski, 1982). Sandberg and others (1988) also studied this collection and concluded that it represents the palmatolepid biofacies of the lower part of the early Famennian Upper crepida Zone.

COcg

Conglomerate--Angular chert-pebble conglomerate, lithic wacke, and limestone breccia present as 0.5- to 25-m-thick zones, which are 20 m to 2 km in length, in the metasedimentary unit (COmm) and exposed in Echo and Colville Valleys. Clasts in the chert-pebble conglomerate are more than 2 mm in diameter and include angular and stretched clasts of chert with radiolarian ghosts (R. C. Roback, Univ. of Texas, Austin, oral commun., 1989), quartz, and argillite in a fine-grained matrix of chert, quartz, sericite, organic matter, pyrite, and hematite. The unit includes 25 m of limestone at the top of the sequence, of which the upper 7-10 m is breccia characterized by angular clasts, as much as 5 cm in length, of gray, thinly laminated limestone and dark-gray argillaceous limestone with some oolitic limestone in a matrix of lime-rich argillite. It has a sharp, but presumably conformable contact with greenstone (COmv) (Hogge, 1982; Brainard,1982).

COmm

Metasedimentary rocks--Dark-gray to black, calcareous and noncalcareous, fine-grained, thinly laminated, medium-bedded argillite, slate, quartzite, and wacke. Fine-grained rocks contain quartz and muscovite with subordinate detrital, subangular quartz grains, chlorite, pyrite, and plagioclase. In places the fine-grained rocks contain as much as 30 percent calcite and 20 percent carbonaceous material and are interbedded with minor chert. Fragments in the poorly sorted, light- to medium-gray, lithic wacke are composed of angular clasts of chert (60-70%), quartz (0-25%), and angular to subangular argillite and tuff clasts (2-20%), generally in a noncalcareous matrix. The unit exhibits small-scale polyphase deformation features (Laskowski, 1982). From north to south the thickness, grain size, percentage of lithic fragments, and amount of tuffaceous rock fragments in this unit increase (Hogge, 1982; Brainard, 1982).

Devonian Metasedimentary Rocks North of Metaline Falls

uDcb

Limestone on Limestone Hill (Upper Devonian)--Medium-gray, grain-supported, thin- to medium-bedded and bedded limestone with few recognizable sedimentary or biogenic features that is present at a single location 12 km north of Metaline Falls. The unit is fairly pure limestone, containing 1.5 to 5 percent insoluble residue (clay minerals and authigenic quartz). The limestone is approximately 210 m thick and locally grades into limestone that contains abundant frosted quartz grains. Megafossils include tabulate and rugose corals, stromatoporoids, bryozoa, brachiopods, foraminifera, echinoderms, and trilobites. Corals identified by A. Riddle and conodonts indicate a Frasnian age (Greenman and others, 1977). The unit is in fault contact with the Middle Devonian limestone and limestone conglomerate (mDcg) (Greenman, 1976; Greenman and others, 1977).

mDcg

Limestone and limestone conglomerate (Middle Devonian)--Polymictic conglomerate with clasts of dark-gray, finely crystalline limestone (92%), siltstone, and mudstone at the base of Limestone Hill. Flattened clasts average 4.5 cm in length and are generally aligned with bedding. Limestone clasts contain abundant crinoid columns, echinoderm plates, brachiopods, and gastropods. The matrix of the conglomerate is light-gray quartz sand and bioclastic limestone containing crinoid columns, gastropods, brachiopods, fenestrate bryozoans, and tabulate coral fragments. Conodonts in the matrix are of Middle Devonian (early Givetian) age, whereas conodonts from clasts have diverse Early and Middle Devonian (Lochkovian, Emsian, and early Eifelian) ages (Greenman, 1976; Greenman and others, 1977). Johnson and others (1988) suggest that the matrix of the conglomerate probably encompasses the lower part of the <u>ensensis</u> Zone (late Eifelian). This unit is considered by Johnson and others (1988) to be outer-shelf-basin rocks with clasts derived from a source area from the west.

Silurian Metasedimentary Rocks North of Metaline Falls

Scg

Quartz-granule conglomerate on Basalt Hill (Silurian)--Dark-gray, angular to well rounded, quartz- and chert-granule-bearing conglomerate interbedded with subordinate slate. Exposed on Basalt and Beaver Hills, west of the Pend Oreille River, 6.5 km north of Metaline Falls. The unit includes phyllite and mudstone clasts in claystone or fine-grained matrix similar to clast composition, and it is interbedded with blue-gray noncalcareous slate. Conglomerate is texturally immature and mineralogically mature, probably reflecting a nearby source area rather than a great distance of transport. Graptolites recovered from the slate are probably monograptids; a Late Silurian age is favored, considering bounding relations (Greenman and others, 1977).

Smm

Metasedimentary rocks--Highly weathered, thin-bedded, graptolitic, gray siltstone, blue-gray argillite, gray fossiliferous limestone, and packstone. The siltstone contains 45 to 50 percent silt-size quartz grains and silica cement and as much as 27 percent calcite cement; clay-size material comprises the remainder. The coarse-grained packstone contains tabulate corals, crinoidal debris, bryozoans, stromatoporoids, and brachiopods. Graptolites from the argillite and siltite are monograptids which place the age of the rock as Silurian to Early Devonian. At Horsefly Hill the age of the rocks is recognized as late Llandovery to Wenlock (late Early and early Late Silurian). Limestones yielded conodonts of Ludlow age, which at one location is restricted to the <u>latialata</u> Zone of the Ludlovian (Late Silurian; Table 2) (Greenman and others, 1977). The contact with unnamed quartz-granule conglomerate on Basalt Hill (Scg) is sharp on the north slope of Beaver Hill. The contact with the Ledbetter Slate presumed to be gradational (Greenman and others, 1977).

Ordovician, Cambrian, and Older Metasedimentary Rocks

Omm_r

Argillite on Red Top Mountain (Ordovician?)--Dark-gray to black, very fine grained, laminated to massive siliceous rock. In some places the siltite to very fine grained quartzite contains 80 percent or more quartz and various amounts of muscovite; the dark color is likely derived from amorphous carbon. The unit includes beds of medium-grained, slightly dolomitic quartzite and dark-gray dolomite. It was estimated by Yates (1976) to be 600 m thick. It was originally mapped by Yates (1964) as the Emerald Member of the Laib Formation (Maitlen Phyllite) of Fyles and Hewlett (1959). Subsequent mapping by Yates (1976) revealed that the uppermost carbonate on Red Top Mountain was equivalent to the Metaline Formation, and therefore the argillite on Red Top Mountain, which was observed in depositional contact overlying the limestone, has to be younger than the Ordovician-Cambrian Metaline Formation (Yates, 1976).

Omm_l

Ledbetter Slate (Ordovician)--Dark-gray to black carbonaceous and pyritic, calcareous and noncalcareous slate and argillite and interbedded and subordinate quartzite, limestone, and dolomite. The unit was named by Park and Cannon (1943) and was redefined by Dings and Whitebread (1965) to contain only rocks of Ordovician age; however, as mapped here, it probably contains some Silurian strata. Dings and Whitebread (1965) estimated the Ledbetter to be 670 m to 762 m thick in the Metaline Mining District; however, no reliable stratigraphic section is present, and the base is not exposed. A minimum thickness of 790 m has been estimated along Clugston Creek, north of Colville (Schuster, 1976). The formation contains Early through Middle Ordovician graptolites (Dings and Whitebread, 1965; Carter, 1989a, 1989b) and trilobites (Schuster, 1976). The contact with overlying Silurian metasedimentary rocks is probably conformable; the two units are difficult to distinguish without fossil data (Greenman and others, 1977). Contact relations with the underlying Metaline Formation are unresolved. (See discussion in description of the Metaline Formation.)

The formation is informally subdivided near Echo Valley and Onion Creek by Schuster (1976) into three units (below). This stratigraphy and thickness estimates are in many respects similar to those of the sequence in the Metaline Mining District.

(1) Gray argillaceous limestone, slate, and dolomitic siltite, interlaminated and interbedded with black carbonaceous limestone. Limestone contains 70 to 80 percent anhedral calcite, with the remainder of the rock consisting of clay and organic material. The estimated thickness is 500 m in the Colville area (Brainard, 1982). Middle Ordovician conodonts (*Drepanodus* sp., *Erismodus* sp., *Panderodus* sp., and *Microcoelodus* sp.) were collected north of Colville (Hogge, 1982).

A yellowish-brown-weathering carbonate-bearing siltite unit that was mapped by Brainard (1982) on Colville Mountain, where it is thrust over the Cambrian section, is probably part of the Ledbetter. The thin- to thick-bedded rock contains 55 to 60 percent dolomite; 40 to 45 percent subangular, fine-grained quartz; 2 percent muscovite; 1 percent organic material; and minor pyrite (Brainard, 1982).

(2) Gray to dark-gray argillite and slate with subordinate laminated and massive black and gray quartzite in zones that range in thickness from a few centimeters to more than 46 m. The thinner beds are generally very fine grained, whereas the thicker beds contain medium-grained quartzite. Interstices in the quartzite are filled with carbonaceous material and minor calcite cement (Schuster, 1976). Dings and Whitebread (1965) suggest that the quartzite-bearing unit in the Metaline area is most common 305 to 365 m above the base of the Ledbetter. However, J. A. Morton (Resource Finance Inc., written commun., 1989) suggests that the contacts of some quartzite in the Metaline Mining District may be thrust faults, so that their stratigraphic position is uncertain. The maximum thickness of this unit is 579 m in the Clugston Creek area (Schuster, 1976).

(3) Dark-colored, brown-weathering, very thin bedded noncalcareous argillite, shale, and slate that includes 5 to 10 percent fine-grained black to dark-gray limestone and dolomite beds 10 mm to 40 cm thick; estimated to be 457 m thick in the Clugston Creek area (Schuster, 1976).

O€cb$_l$, O€cb$_d$, O€cb$_b$

Metaline Formation (Middle Cambrian to Middle Ordovician)--Light-gray, medium-bedded dolomite; gray, massive limestone; thin-bedded, interbedded limestone and shale; and intraformational breccia. The formation is generally informally subdivided into an upper limestone unit, a middle dolomite unit, and a lower interbedded limestone and shale unit (Park and Cannon, 1943; Dings and Whitebread, 1965). These units, however, intertongue and are lenticular, and irregular masses of the dolomite are present in both the upper and lower units. Dings and Whitebread (1965, p. 10) indicated that "it should be clearly kept in mind that...[carbonate units] are lithologic units rather than members of a formation having definite time significance and stratigraphic positions." In addition, lateral facies changes occur throughout the region (Bending, 1983; J. A. Morton, Resource Finance Inc., oral commun., 1989). Park and Cannon (1943) assigned a total thickness for the formation of 914 m for what Dings and Whitebread (1965) indicate is an incomplete section; Dings and Whitebread (1965) estimated a total thickness of in excess of 1,600 m in the Metaline Mining District.

The formation was named by Park and Cannon (1943) for rocks exposed near Metaline Falls and given a Cambrian age on the basis of the trilobites collected by them from the main Lehigh quarry (Table 2). However, more recently collected conodont (Repetski, 1978; Repetski and others, 1989; Schuster and others, 1989), graptolite (Carter, 1989a), and vertebrate (Repetski, 1978) fossils indicate that the Metaline Formation is probably Late Cambrian to Middle Ordovician in age (Table 2). The co-occurrence of Oepikodus communis (Ethington and Clark) and other conodont species documents the occurrence of the O. communis Zone (Fauna E, in part; middle Arenigian; late Ibexian) of Early Ordovician age for a collection taken 30 m below the contact with the Ledbetter Slate along Clugston Creek, north of Colville (Repetski and others, 1989; Schuster and others, 1989). Conodonts from the very top of the Metaline Formation, at Clugston Creek indicate it is at least as young as latest Arenigian or Llanvirnian (Whiterockian; Middle Ordovician) (Repetski and others, 1989; Schuster and others, 1989).

The nature of the contact of the Metaline Formation with Ledbetter Slate is unresolved. Schuster (1976) and Mills (1977, p. 28) suggested that the contact is an unconformity. Hurley (1980, p. 128) indicated that the contact between the Metaline Formation and the Ledbetter Slate includes segments which are of fault, disconformity, angular unconformity, and depositional origin. J. A. Morton (Resource Finance Inc., written commun., 1988) concluded that the contact is conformable and that the

> "deep water debris flow deposits, turbidites, and basinal mudrocks of the Josephine unit...[are] gradational, interbedded, and interfingered...with the Ledbetter, reflecting a local depositional transition which varies in age from the Lower Ordovician Oncograptus Zone to the early Middle Ordovician Paraglossograptus tentaculatus Zone."

Carter (1989a) concluded that the presence of graptolites of the Paraglossograptus tentaculatus Zone (Middle Ordovician) on either side of the contact in the Pend Oreille mine supports the interpretation of a conformable, depositional transition between the Ledbetter Slate and the Metaline Formation.

O€cb$_l$

Massive limestone--Light- to medium-gray, very fine grained, massive, irregularly mottled limestone, locally containing white to medium-gray, rounded and crudely ellipsoidal chert nodules that average less than 3 cm in length (Park and Cannon, 1943). This limestone is interbedded with thin shale beds in its upper 10 m in the Metaline Mining District (Dings and Whitebread, 1965). The unit thickens from 0 m east of the Pend Oreille River to 600 m in the Metaline Mining District (J. A. Morton, Resource Finance Inc., written commun, 1990); Dings and Whitebread (1965) estimate the thickness of the unit at more than 450 m in the Lead King

Hills, north of Metaline Falls. It pinches out near the Pend Oreille and Grandview mines. It is irregularly dolomitized near mineral deposits (Dings and Whitebread, 1965) or, alternatively, considered by Bending (1983) to be a lateral facies of the bedded dolomite in the Metaline Mining District. Schuster (1976) estimated that the thickness of the upper part of the Metaline (limestone unit) is 1,097 m at the west end of Uncle Sam Mountain. Within 60 m of the Spirit pluton the unit is more coarsely crystalline, bleached, and dolomitized (Schuster, 1976).

Stromatolites and oncolites are present at the eastern exposures of the unit (Bending, 1983). Early and Middle Ordovician conodonts were identified from near the top of the unit in the Clugston Creek area (Schuster and others, 1989). Early and Middle Ordovician graptolites are present in interfingering black shale lenses in the Josephine unit in the Pend Oreille mine near the contact with the Ledbetter Slate (J. A. Morton, Resource Finance Inc., written commun., 1988; Carter, 1989a). Bending (1983) suggests that the rocks represent a subtidal shallow shelf depositional environment.

O€cb$_d$

Bedded dolomite--Cream-white, light-gray, and black, medium- to thick-bedded, fine- to medium-grained dolomite with minor quartz (Park and Cannon, 1943; Dings and Whitebread, 1965; Yates, 1976). The dolomite is interbedded with intraformational breccia, which includes the Josephine unit (McConnel and Anderson, 1968; Addie, 1970), siliceous dolomite, limestone, black dolomite, and massive gray, fine- to medium-grained dolomite with no apparent bedding features. The unit also includes recrystallized and siliceous dolomite associated with lead and zinc deposits in the Metaline Mining District. Bedding is poorly developed; rare desiccation cracks and gypsum or gypsum psuedomorphs can be found in the upper part (associated with mineral deposits) (Bending, 1983). Schuster (1976) estimates the unit to be 1,402 m thick in the Clugston Creek area; the thickness is estimated at 1,247 m in the Metaline area near the international border (Dings and Whitebread, 1965). Where it is adjacent to plutonic rocks, the dolomite is clean, white, coarse-grained, dolomitic marble and calc-silicate rock.

The intraformational breccia consists of dolomite fragments in a fine-grained, dark-gray, dolomite matrix which alternates in 8- to 100-m-thick sections with dark- to light-gray, medium- to fine-grained, thin-bedded dolomite (Yates, 1976). This breccia was mapped by Yates (1964, 1976) east of Cedar Lake and Deep Lake. Breccia fragments are thin, subangular to angular, 1-cm- to 1.5-m-long slabs broken parallel to bedding. Some clasts are preferentially oriented; they are commonly rotated. The breccia has a gradational contact with the bedded dolomite (Yates, 1976).

The Josephine unit (McConnel and Anderson, 1968; Addie, 1970; J. A. Morton Resource Finance, Inc., written commun., 1988, 1990) is a complex assemblage of irregularly interlayered and massive, laminated clastic rock to breccia which includes clasts of black and dark-gray, variously silicified and weakly to intensely pyritic dolomite, dolomitic breccia, limestone, argillite, and quartzite. Some fragments have distinct angular margins or are highly irregular and wispy, and have indistinct borders that appear to grade into the dolomite matrix. Fragment size ranges from sand-size to 3-m-wide blocks (McConnel and Anderson, 1968). This unit is present below the Ledbetter contact, and it laterally interfingers with the gray limestone (O€cb$_l$) and bedded dolomite (O€cb$_d$) units. Interpretations of the origin of the breccia units include a fault breccia (Park and Cannon, 1943; Dings and Whitebread, 1965), solution collapse (Mills, 1977), and debris flow and slump deposits (McConnel and Anderson, 1968; J. A. Morton, written commun., 1988).

Yellowhead-type Zn-Pb mineralization is found in 3- to 6-m-thick stratabound, lenticular and sharply defined sulfide-rich layers 300 to 350 m below the top of the Metaline Formation (Bending, 1983). Sulfide mineralization in the Josephine unit generally is present in the bedded dolomite unit

10 to 60 m below the Ledbetter contact (Dings and Whitebread, 1965). In mineralized areas, the Josephine unit locally has a pyrobituminous and dark, siliceous matrix that contains finely disseminated sphalerite and pyrite and lesser galena, quartz, calcite, and dolomite (Bending, 1983). The Josephine unit, as well as other units of the Metaline Formation, are cut by and included as fragments within crudely stratiform to sharply discordant bodies of very coarse grained calcite that locally contains significant amounts of jasperoid, quartz, sphalerite, and galena (J. A. Morton, Resource Finance Inc., written commun., 1990).

The Josephine unit contains dark-gray crytagal laminae with fenestral textures, oncolites, oolites, peloids, and pellets (Bending, 1983). Early Middle Cambrian phosphatic brachiopods were found in intraformational breccia on the west slope of Gladstone Mountain (Yates, 1976).

O€cb_b

Bedded limestone--Thin-bedded to laminated, dark-gray, limestone interbedded with dark-gray to black shale, phyllite, calcareous phyllite, and limy dolomite, locally containing argillite, and black, pyritic, carbonaceous shales and breccia (Dings and Whitebread, 1965; J. A. Morton, Resource Finance, Inc., written commun., 1988). Schuster (1976) estimated the bedded limestone to be 914 m thick in the Clugston Creek area; Dings and Whitebread (1965) measured a 288-m-thick section in the Metaline Mining District. Bleaching, coarsening of carbonate grain size, and development of mica have been noted adjacent to intrusive rocks (Schuster, 1976). The unit contains trilobites and phosphatic brachiopods of early Middle Cambrian age (Park and Cannon, 1943; Dings and Whitebread, 1965). Bending (1983) suggests that the presence of trilobites indicates an open marine platform or shallow basin environment. The unit has a gradational contact with underlying Maitlen Phyllite (Dings and Whitebread, 1965).

€phm, €cb

Maitlen Phyllite (Early Cambrian)--Light-green, green-gray, and dark-gray, fine-grained, thin-bedded to medium-laminated phyllite with thin beds and laminae of quartzite, carbonate, and sericite schist. The phyllite is composed of quartz, muscovite, plagioclase, pyrite, limonite, and chlorite, with accessory zircon, garnet, sphene, apatite, and tourmaline. Porphyroblasts of andalusite (or sillimanite) and cordierite are present in schistose rocks near the Spirit pluton (Yates, 1976). The structural style of the Kootenay arc is well displayed as minor folds in the ductile rocks of the Maitlen Phyllite. Where S_1 is parallel to S_0, much of the bedding is probably transposed.

Phyllite appears to decrease, and carbonate rocks increase westward in the Maitlen Phyllite; however, apparent changes in thickness could be the result of repetition due to structure rather than true facies changes. East of the Pend Oreille River, Miller (1983) estimates the section is 2,650 m thick, but this measurement was calculated from a map and does not take into account folding and faulting (F. K. Miller, USGS, written commun., 1990). There, the

> "upper half of the formation grades from almost pure phyllite to phyllitic limestone...[composed of] thin beds of dark gray impure limestone and dolomitic limestone with phyllitic partings... Most of [the] lower part is pale gray-green phyllite with 1 to 10 cm interbeds of tan or gray argillaceous quartzite" (Miller, 1983, p. 4).

Yates (1976) estimates the thickness near Abercrombie Peak at 1,000 m.

West of the Leadpoint fault, the unit thins and carbonate rock comprises nearly 50 percent of the section west of the Columbia River (Yates, 1970, 1976; Phillips, 1979). Phillips (1979) measured 300m to 316 m (including the Reeves Limestone Member) of the Maitlen Phyllite west of the Columbia River near Bowen Lake. There, the unit consists of gray-green to silver-gray phyllite and minor quartzite interbedded with 10- to 50-m-thick sections of limestone.

Park and Cannon (1943), Dings and Whitebread (1965), Yates (1976), and Fischer (1981) suggest that the Metaline Formation grades into the Maitlen Phyllite in the Metaline Mining District. The contact with the Maitlen Phyllite is placed where noncalcareous phyllite exceeds carbonate-bearing rock (Schuster, 1976). In the Clugston Creek area the contact between the Metaline Formation and the Maitlen Phyllite is faulted, except near the east end of Uncle Sam Mountain (secs. 1 and 12, T. 37, N., R. 39 E.) where the contact is conformable and gradational (J. E. Schuster, DGER, written commun., 1989).

Ꞓcb

Limestone and dolomite (includes the Reeves Limestone Member of the Maitlen Phyllite and other mapped limestone bodies)--White, cream-white, and medium- to light-gray, medium- to coarse-grained, laminated to massive limestone, and dolomitic limestone, interbedded with other lithologies of the Maitlen Phyllite. The unit contains minor rounded quartz grains and muscovite. The basal limestone, which contains Early Cambrian archaeocyathids (Little, 1960), is 15 to 120 m thick and is referred to as the Reeves Limestone Member (Yates, 1976). The Reeves Limestone Member was named for exposures in the Reeves McDonald mine in southern British Columbia (Fyles and Hewlett, 1959), and the name was first applied in Washington by Yates (1964). Limestone units above the Reeves Limestone are not named; seven limestone beds are identified in Canada (Fyles and Hewlett, 1959). Archaeoyathid-bearing beds are present in the Colville quadrangle on Colville Mountain (R. G. Yates, USGS, written commun., 1985) and in the Gillette Mountain and Aladdin quadrangles (J. E. Schuster, DGER, written commun., 1988). Archaeocyathids (Ethmophyllum and Pseudosyringochema [sic]) are present in the lower limestone (Reeves Limestone Member) near Douglas Lake, and ghosts of archaeocyathids are present in a 60- to 120-m-thick dolomite unit above the Reeves, separated from the Reeves by 100 to 130 m of gray-green argillite (Hampton, 1978).

ꞒZq

Gypsy Quartzite, undivided (Lower Cambrian-Precambrian Z)--Light-gray and purplish, thick-bedded quartzite interbedded with gray, tan, green, and purplish argillite and siltite. The formation was named by Park and Cannon (1943) for outcrops northeast of Metaline Falls. Miller (1983) estimates the thickness at 1,425 m east of the Pend Oreille River. Lindsey (1988) measured a 1,350-m section on Sullivan Mountain, and Groffman (1986) measured a 1,855-m section near Gypsy Peak. The unit is 30 percent thinner on the west side of the Flume Creek fault (Burmester and Miller, 1983). The lower 1,000 m to 1,300 m of the Gypsy are dominated by quartzite containing minor interbedded argillite and siltite; the upper 350 m to 450 m comprise an interbedded sequence of quartzite, siltite, and argillite (Lindsey and others, 1990).

The position of the contact between the Maitlen Phyllite and the Gypsy Quartzite has not been consistently mapped. Park and Cannon (1943, p. 13) placed it at the "top of a band, 50-300 feet thick...characterized by fucoidal cylinders and unidentified crooked rods of organic (?) origin" 20 m to

40 m below the Reeves Limestone Member (Lindsey, 1987). Miller (1982b), however, suggests that the contact be placed at the base of the Reeves Limestone Member, where present. Many mappers, including Miller and Yates (1976), Yates (1964), and Burmester and Miller (1983), have used the definition of the contact as defined by Miller (1982b). Where the Reeves Limestone Member is absent, Lindsey and others (1990) suggest that the contact be placed where interbedded brown quartzites typical of their upper argillite unit (see below) are replaced by black and green phyllite typical of the Maitlen Phyllite; this transition is gradational and is as much as 30 m thick. Contacts shown on Plate 1 reflect all these definitions.

The location of the lower contact of the Gypsy Quartzite is also in dispute. Park and Cannon (1943, p. 15) included "grits and sandstone" in the lower part of the Gypsy Quartzite. Miller (1983) mapped the quartzite, conglomeratic quartzite, conglomerate, phyllitic quartzite, and phyllite in the lower part of the Gypsy Quartzite of Park and Cannon (1943) as the Three Sisters Formation following the usage of Walker (1934). Miller (1983) concluded that the contact is sharp and that the Three Sisters Formation unconformably underlies the Gypsy Quartzite; he placed the contact at the top of the highest granular conglomerates (Miller, 1982b). Lindsey (1987) suggests that the lower 50 m of the Gypsy as mapped by Miller (1982b) contains conglomerate similar to the Three Sisters Formation, representing a transition zone, and thus indicating a conformable contact. On Ruby Mountain, the Gypsy unconformably overlies the Striped Peak Formation of the Belt Supergroup; Windermere age rocks are not present.

Lindsey (1987) suggests that the Precambrian-Cambrian boundary is present in the Gypsy Quartzite, somewhere below the first occurrence of trilobite fragments. He reasoned that unfossiliferous rocks, for which a sedimentary environment similar to that for the trilobite-bearing sediments is indicated, are Precambrian in age and were deposited before the first appearance of the fauna. The Gypsy Quartzite is correlated with the Addy Quartzite of Weaver (1920) (Lindsey, 1987, 1988; Groffman, 1986). Lindsey (1987) suggests that the Gypsy Quartzite may be slightly older than the Addy Quartzite because a Lower Cambrian fauna first occurs slightly higher in the section in the Gypsy.

The formation is present in the cores of regional anticlines. It was deposited on a passive margin in a rapidly subsiding basin formed by rifting of the North American continent in the late Precambrian to Early Cambrian (Lindsey, 1987).

The Gypsy Quartzite has been divided into five informal units east of the Pend Oreille River by Groffman (1986) and Lindsey (1987, 1988). This basic stratigraphy is represented throughout the map area. West of the Flume Creek fault the thickness of the Gypsy Quartzite is about 30 percent less (Burmester and Miller, 1983).

ꞒZq$_1$

Upper argillite unit--Brown to olive-green argillite and gray to tan argillitic quartzite, conglomerate, and quartzite. The unit contains some thin beds of carbonate-bearing quartzite and is approximately 350 to 480 m thick. Vertical burrows of *Scolithus bulbus* and horizontal burrows of *Planolites beverlyensis* (Lindsey, 1987) and trilobite fragments (Groffman, 1986) have been found.

On Old Dominion Mountain and Ruby Mountain, west of the Pend Oreille River, thick-bedded, white quartzite with carbonate cement is located at what probably is the base of this unit. The carbonate-cemented quartzite is in possible fault and/or stratigraphic contact with orange dolomite of the lower dolomite of Miller (1974b).

€Zq$_2$

Coarse quartzite and argillite unit--White to tan, medium- to very thick bedded, fine-grained to granular quartzite with abundant planar and trough cross-beds, interbedded with thin lenticular interbeds of argillite and siltite. The lower 30 m to 60 m consists of sequences of white and brown, fine- to coarse-grained, thin- to medium-bedded quartzite alternating with green and brown argillite and minor conglomeratic quartzite. The unit is approximately 150 m to 260 m thick (Lindsey and others, 1990), and contains burrows of Scolithus linearis Haldeman (Lindsey, 1987). The lower contact is placed at the top of the lowest white and tan quartzite above the unit in which blue to purplish quartzite is dominant.

€Zq$_3$

Purple quartzite unit--Purple, light-blue, white to light-gray, medium- to coarse-grained, thin- to thick-bedded quartzite. The unit is approximately 600 m to 690 m thick. It displays purple to red liesegang bands which are parallel, subparallel, and transverse to bedding. Liesegang bands, hematitic cements, and heavy-mineral laminae define banding that is most prominent in the lower 400 m to 450 m. The upper 200 m to 300 m consist of medium- to thick-bedded, blue and purple, medium-grained to granular quartzite with planar cross-beds. Scolithus linearis burrows are present in the upper part (Lindsey and others, 1990). The base of unit is placed at the bottom of the lowest purple and blue quartzite (Lindsey, 1988).

€Zq$_4$

Lower argillite unit--Lenticular to wavy bedded, olive and brown argillite interbedded with brown, tan, and white, fine-grained quartzite. The unit coarsens upward and is approximately 95 m (Groffman, 1986) to 120 m (Lindsey, 1987) thick. It contains sand-filled vertical burrows (Lindsey, 1987).

€Zq$_5$

Basal quartzite unit--White, medium- to thick-bedded, fine- to medium-grained, well-sorted, planar cross-bedded, quartzite (quartz arenite) and rare argillite that is restricted to thin (<1 m) beds. The unit is approximately 250 m to 350 m thick. Medium- to thick-bedded, lenticular interbeds of pebble conglomerate filling shallow channels are common in the lowermost 10 m to 30 m of the unit (Lindsey and others, 1990).

Pzq

Quartzite of Miller (1974b) (Paleozoic)--Sixty percent medium- to dark-gray phyllite and 40 percent medium-bedded to massive, white to gray, carbonate-bearing, vitreous quartzite that crops out on Ruby Mountain. The phyllite has indistinct bedding and is highly cleaved. The unit contains sequences composed of as much as 60 m of phyllite alternating with sequences of quartzite as much as 30 m thick. The maximum thickness is 732 m near the Silver King mine in the Chewelah 1:100,000-scale quadrangle. The unit is considered by Miller (1974b) to be younger than the lower dolomite of Miller (Miller, 1974b). However, it resembles the upper part of the Gypsy Quartzite (Addy Quartzite) and the lower part of the Maitlen Phyllite. In part, it also resembles the carbonate-bearing quartzite and carbonate interbeds in the Gypsy Quartzite near its contact with the Maitlen Phyllite on the southwest flank of Old Dominion Mountain.

Pzcb

Upper dolomite of Miller (1974b) (Paleozoic)--Thick-bedded, medium-gray and pale-tan dolomite with some darker beds. The unit crops out west of Ruby Mountain, west of the Pend Oreille River. Much of the rock is brecciated and recemented. This dolomite is approximately 305 m thick and faulted against the lower dolomite of Miller (1974b). Miller (1974b) could make no satisfactory correlation; however, this unit most likely represents part of the Metaline Formation.

$Pzcb_l$

Lower dolomite of Miller (1974b) (Paleozoic)--White, pale-gray or pale-tan, fine- to coarse-grained dolomite with some medium- to dark-gray interbeds that crops out near Gardner Creek. Beds range in thickness from a few centimeters to 3 m and averages 0.6 m. No sedimentary structures have been recognized. This unit is approximately 213 m to 274 m thick on the west flank of Ruby Mountain. Much of rock is brecciated and recemented.

The contact with the Gypsy (Addy) Quartzite is nowhere exposed; however, the contact between the two units can be approximately placed within 30 m of exposed outcrop of each unit on the west flank of Ruby Mountain. Yellowish light-brown dolomite cements coarse-grained, rounded-grained quartzite; the dolomite content decreases toward the contact with the Gypsy (Addy) Quartzite. A similar relation is observed at the top of the Addy (Gypsy) Quartzite where that formation appears to be in stratigraphic contact with the mottled dolomite of the Metaline Formation west of the Jumpoff Joe fault on the Chewelah and Nespelem 1:100,000-scale quadrangles. The lower dolomite of Miller (1974b) may therefore represent part of the lower part of the Metaline Formation.

Precambrian Metasedimentary and Metavolcanic Rocks

Windermere Group

The Three Sisters Formation (Zqt), the Monk Formation (Zmm_m), the Leola Volcanics (Zmv_l), and the Shedroof Conglomerate (Zph_s, Zcb_s, Zcg_s) make up the Windermere Group in the Colville 1:100,000-scale quadrangle. These heterogeneous metasedimentary and metavolcanic 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 Cambrian (Devlin and others, 1988). The Windermere Group unconformably overlies the Priest River Group and may be in conformable (Lindsey, 1987; Groffman, 1986) or in unconformable (Miller, 1982b) contact with the overlying Gypsy Quartzite.

Because rocks were deposited in several fault-bounded basins, rock type and thickness vary markedly throughout the region. East of the Pend Oreille River two distinct facies have been mapped, and major thickness changes are noted on either side of the northwest-dipping Helmer Creek fault (Miller, 1983). The Windermere section southeast of the Helmer Creek fault is much attenuated, lithologically different, and commonly finer grained than the homoclinal section northwest of the fault. Rocks that make up the homoclinal section are distinctly less deformed than rocks southeast of the Helmer Creek fault, where the frequency and tightness of large-scale folds increases southeastward from the fault. Windermere rocks east of the Helmer Creek fault are deposited on Precambrian Y Priest River Group rocks which may be slightly lower in the stratigraphic section than Precambrian Y rocks on the west side of the fault, suggesting greater depth of pre-Windermere erosion on the eastern block (Miller, 1983).

The Windermere Group is absent on the west flank of Ruby Mountain in the southeast part of the map area. There, the Gypsy (Addy) Quartzite directly overlies the Precambrian Y Striped Peak Formation of the Belt Supergroup (Miller, 1974b).

Zq_t

Three Sisters Formation (Precambrian Z)--White, light-blue, and gray, thin- to thick-bedded, coarse-grained to granular, texturally immature quartzite, and interbeds of pebble conglomerate and argillite. Pebble conglomerate is generally restricted to the lower half of the unit and contains clasts of polycrystalline quartzite, quartz mica tectonite, chert, and monocrystalline quartz. Argillite in the lowermost part of the unit consists of thin-bedded, gray, brown, and black micaceous argillite and siltite with lenticular interbeds less than 1 m thick of limestone, dolomite, and fine-grained quartzite (Lindsey and others, 1990). A single basaltic greenstone flow and minor volcaniclastic rock are present in the upper part (Miller, 1983). The unit is approximately 2,100 m thick east of the Flume Creek fault and 600 m to 1,200 m thick west of the fault (Burmester and Miller, 1983).

The Three Sisters Formation was included in the Gypsy Quartzite by Park and Cannon (1943); it was redefined by Miller (1983) following the concepts of Walker (1934) for rocks of similar lithology and stratigraphic position in southeastern British Columbia. The contact with the overlying Gypsy Quartzite is thought to be conformable by Groffman (1986) and Lindsey (1987) and unconformable by Miller (1983). Lindsey and others (1990) redefined the lower contact of the Three Sisters Formation and assigned the argillite in the lower part to the Monk Formation so that all argillite above the Leola Volcanics and beneath the Gypsy Quartzite is in one formation. However, for this report the contact with the Monk Formation is used as defined by Burmester and Miller (1983).

Zmm_m

Monk Formation (Precambrian Z)--Dark-gray to black, thin-bedded, argillite, siltite, and phyllitic argillite with local limestone, diamictite, quartzite, and greenstone interbeds. Thickness and stratigraphy vary throughout the region.

East of the Pend Oreille River, the formation is approximately 1,150 m thick northwest of the Helmer Creek fault. It includes highly cleaved argillite and carbonaceous argillite; tan, thin-bedded to massive carbonate rock; and tan-weathering diamictite. Quartzite and carbonate content increase up-section. The lower 150 meters contain discontinuous zones of a conglomerate that has a green matrix and a high proportion of volcanically derived materials, as well as green-gray argillite of possible volcanic origin. The formation rests with apparent unconformity on the Leola Volcanics and grades upward into the Three Sisters Formation (Miller, 1983).

Southeast of the Helmer Creek fault, dark-gray and black, thin-bedded to thinly laminated argillite and tan, poorly sorted, arkosic quartzite dominate; pyrite is abundant. One-half- to 1-mm-diameter, blue-gray quartz grains are common, but nowhere do they exceed 1/2 percent of rock (Miller, 1983). Approximately 500 m of section is preserved, (Miller, 1983).

West of the Flume Creek fault (Fig. 6), west of Ione, only the upper 240 meters of the Monk Formation is preserved. There, the formation consists of white to cream-colored, massive, coarse-grained dolomite. East of the Flume Creek and Harvey Creek faults, the lower part of the formation is made up of diamictite, phyllite, quartzite, and thin-bedded, interlaminated phyllite, quartzite, and dolomite (Burmester and Miller, 1983).

Medium-bedded, medium brown-gray to dark-gray siltite, quartz-rich siltite, and argillite with thin to medium laminae delineated by carbonate minerals and disseminated and clotted pyrite on Blacktail Butte, Green Mountain, and in the Bon Ayre Valley is probably the Monk Formation. Black quartz-biotite schist is present where the formation is near intrusive rocks. Interbedded limestone beds are rare. North of the Longshot mine, quartz-mica and andalusite-bearing schists are found in a band 38 to 45 m thick and have a strike length of several kilometers; these schists are thought to be derived from the Monk Formation (Thorsen, 1966). The thickness is calculated to be more than 1,000 m; however, this value does not take into consideration repetition of the section by folding or faulting. The formation generally does not exhibit small-scale folds. The Monk Formation in this area, is in fault contact with Leola Volcanics and Maitlen Phyllite.

Zmv_l

Leola Volcanics (Precambrian Z)--Basaltic greenstone flows, flow breccia, tuff, and volcaniclastic rocks; minor conglomerate and diamictite in the lower part. Individual flows, as much as 25 m thick, are massive and show few primary or secondary internal features. Well-developed pillows are present in the lower few hundred meters of the unit and locally higher in the section. The greenstone is commonly sheared and phyllitic. The formation is approximately 1,530 m to 1,850 m thick in the Sullivan Creek area and as much as 475 m thick in the Pass creek area (Miller, 1983).

This unit includes amphibolite, mafic gneiss, and greenstone on Aladdin, Green, and Huckleberry Mountains. Greenish-black, fine-grained, massive amphibolite contains streaks, lenses, and porphyroblasts of plagioclase (An_{10-30}) and hornblende in a matrix of chlorite, quartz, and biotite, with minor sphene, epidote, garnet, diopside, calcite, and ilmenite (Thorsen, 1966).

The contact with the Shedroof Conglomerate is conformable and placed at the base of the lowest massive flow (Miller, 1983). The formation is correlated with the volcanic member of the Huckleberry Formation to the southwest in the Chewelah 1:100,000-scale quadrangle and the Irene Volcanics in southern British Columbia.

K-Ar dates from the Huckleberry Formation 97 km to the southwest range from 238 to 928 Ma and cluster between 613 and 862 Ma (Miller and others, 1973; recalculated using current IUGS constants, Steiger and Jaeger, 1977). Devlin and others (1985) found that the Rb-Sr isotopic system of the metavolcanic rocks had been severely disturbed, and they suggest that the K-Ar ages do not reflect the age of extrusion. Sm-Nd whole-rock and mineral separate ages from the same site at the base of the Huckleberry Formation suggest extrusion at 674 ± 212 Ma, but most likely at 762 ± 44 Ma (Devlin and others, 1988).

Zph_s, Zcb_s, Zcg_s, Zq_s

Shedroof Conglomerate (Precambrian Z)--Coarse conglomerate, diamictite, grit, quartzite, silty quartzite, phyllite, black slate, and dolomite (Park and Cannon, 1943), whose thickness and stratigraphy vary locally and across major faults.

Northwest of the Helmer Creek fault the apparent thickness of the section is 3,250 m, but this does not take into account structural thickening by numerous closely spaced faults and cleavage. The unit there contains boulder and pebble conglomerate, diamictite, and quartzite in the lower part and conglomerate in a green chlorite and epidote matrix with thin basalt flows, phyllite, quartzite, and wacke in the upper part. Green beds are progressively more abundant higher in the formation and may reflect increasing pyroclastic material related to the onset of volcanism associated with the Leola Volcanics.

The 150- to 250-m-thick section south of the Helmer Creek fault consists of gray-white, fine- to medium-grained, vitreous quartzite (Miller, 1983). In Rocky Creek, south of Sullivan Lake, the unit is 300 m thick and contains conspicuous pebble- to boulder-size, angular and subrounded, stretched clasts of buff-colored dolomitic limestone. This formation unconformably overlies at least two units of Priest River Group rocks; it has a gradational contact with overlying Leola Volcanics (Miller, 1983).

Zph_s

Phyllite--Gray-green, sandy phyllite that forms the middle part of the Shedroof Conglomerate north of the Helmer Creek fault and above the quartzite unit (Zq_s) at some places southeast of the Helmer Creek fault where the phyllite ranges from 0 to 100 m in thickness. The unit is as much as 2,000 m thick northwest of the Helmer Creek fault (Miller, 1983).

Zcb_s

Limestone--Two or more 150-m-thick and several kilometers-long lenses of impure brownish-gray to gray, slightly dolomitic limestone and limestone in the phyllite unit (Zph_s). This limestone contains numerous sand-size quartz grains and abundant argillaceous material (Miller, 1983).

Zcg_s

Conglomerate--Poorly sorted, rounded to subrounded, tan to rusty brown and green, boulder and pebble conglomerate and diamictite. Clast size ranges from more than a meter to less than a centimeter. Groundmass material is sand size and contains varied amounts of carbonate minerals. Quartz, quartzite, tan dolomite, and argillite are the most abundant clasts; granitic clasts are locally abundant. Most clasts are flattened and show preferred orientation parallel to a pervasive cleavage everywhere developed (Miller, 1983).

Zq_s

Quartzite--Pale-gray to white, fine- to medium-grained, vitreous quartzite that is generally restricted to northwest of the Helmer Creek fault. The unit is thick bedded to massive and has little internal stratification. It locally contains clasts of angular quartzite (as much as 1 cm in diameter) and interbedded argillite beds. Sparsely disseminated copper sulfide minerals are observed where this unit is crossed by Pass Creek road (sec. 17, T. 38 N., R. 45 E.), where 10 m of diamictite and sandy phyllite are also exposed (Miller, 1983).

Priest River Group

The name Priest River Group was applied by Park and Cannon (1943) to metasedimentary rocks unconformably overlain by the Shedroof Conglomerate. These rocks had been originally termed the Priest River terrane by Daly (1912). Lithologic units in the Priest River Group are the upper argillite (Yar_u), carbonate rock (Ycb_u), lower argillite (Yar_l), quartzite (Yq) and calc-silicate rock (Ycs). Miller (1983) tentatively correlated the Priest River Group with various units in the Belt Supergroup. More recently, Miller and Whipple (1989) suggest that the Priest River Group may be a lateral equivalent of the Deer Trail Group. The Deer Trail Group has been tentatively correlated with the upper part of the Belt Supergroup (McMechan, 1981; Miller and Whipple, 1989). In this report, Precambrian Y rocks are divided into the Priest River Group and the Belt Supergroup. The Priest River Group includes those rocks that are overlain by the Windermere Group and exhibit polyphase deformation. The Belt Supergroup sequences include Precambrian metasedimentary rocks similar to those in the Belt Supergroup to the south on the Chewelah 1:100,000-scale quadrangle that are generally overlain by Addy (Gypsy) Quartzite.

Yar_u

Upper argillite--Black to gray argillite and phyllitic argillite. Tan to gray dolomite and limy dolomite beds as much as 2 m thick are present sparingly in the upper part of unit and are in most places separated by more than 50 m of carbonate-free argillite. Cross lamination, channel-and-fill sequences, and graded beds are present in the laminated part of section. Between Harvey and Noisy Creeks the argillite unit ranges from thinly laminated light- and dark-gray argillite to silty medium-gray argillite with no bedding features. Much of the rock is highly phyllitic and has one or more well-developed slip cleavages in most places. Pencil slate formed where two intersecting cleavages developed. This unit is unconformably overlain by the Shedroof Conglomerate; the lower contact is a fault. The thickness has been calculated at approximately 1,425 m (Miller, 1983).

Ycb_u

Carbonate rock--Thin- to thick-bedded, gray and tan dolomite, limy dolomite, argillite, and siltite with minor limestone. Approximately one-third of the unit is interlayered argillite and siltite; much of the carbonate rock is argillaceous and/or arenaceous. The unit contains at least one carbonate-free argillite zone that is as much as 50 m thick, but is generally less than 10 m thick. Along Gypo Creek, a tributary of Pass Creek, about a quarter of the unit is white, fine-grained dolomitic marble that weathers in 3- to 10-m-thick slabs with fine internal layering. Sparse algal structures are present. This unit forms poor exposures in most places and weathers to a rusty red soil. The calculated thickness ranges from 330 m to 490 m; this variation is due to internal deformation and/or pre-Windermere erosion. The unit is unconformably overlain by quartzite of the Shedroof Conglomerate (Miller, 1983).

Yar_l

Lower argillite--Light- to dark-gray, laminated phyllite, argillite, and siltite interbedded with tan, thin- to thick-bedded, carbonate-bearing, fine-grained quartzite and siltite. Carbonate-bearing beds pinch and swell; the bed thickness varies from 1 cm to 3 cm. Filled syneresis cracks are locally abundant. The argillite grades down into increasingly more quartzitic rock. Where thermally metamorphosed, the unit includes quartz-rich calc-silicate rock. The thickness of unit varies because of internal faulting, folding, and slip cleavage (Miller, 1983).

Yq

Quartzite--White to light-gray, medium- to thick-bedded, medium-grained to granular, vitreous quartzite with disseminated pyrite and rare argillaceous interbeds.

The unit crops out west of the Pend Oreille River along Meadow Creek and east of the Pend Oreille River in Dry Canyon, and south of Pass Creek. Near Meadow Creek light-green to white, chloritic, finely layered calc-silicate rock with minor marble is in stratigraphic contact with the quartzite. The quartzite is in part interbedded with medium-gray to medium-brown phyllite and cut by mafic dikes. The contact with the Leola Volcanics to the west is covered; amphibolite float is directly adjacent to quartzite outcrops.

Ycs

Calc-silicate rock--The character of the unit depends on the degree of metamorphism and its original composition. In the Harvey Creek area the most common rock types are interlayered white, fine-grained quartzite and brown, white, and pale-green calc-silicate rock. Plagioclase, actinolite, tremolite, and garnet are the most common calc-silicate minerals. The unit includes thick zones of impure marble. Locally, where thermal metamorphism is less intense but dynamic metamorphism is strong, chlorite-bearing phyllite is interlayered with highly cleaved tremolite marble and fine-grained quartzite. Brown layers, which were apparently argillite, are metamorphosed to fine-grained quartz-plagioclase-biotite rock. Layering is S_2; all bedding has been destroyed by slip cleavage prior to or during metamorphism (Miller, 1983).

On Hande Creek, east-northeast of Colville, impure marbles, calc-silicate rock, and hornfels are interbedded with phyllite, quartzite, and schist. Marble is white to green to light gray and has green and tan, contorted bands, which in places contain chlorite, wollastonite, diopside, garnet, and calcite. The contact with the overlying Leola Volcanics is covered; amphibolite float is present adjacent to calc-silicate outcrops (Thorsen, 1966).

Belt Supergroup

The sequence of upper Proterozoic (Precambrian Y) metasedimentary rocks that is overlain by the Gypsy (Addy) Quartzite in northeastern Washington has been correlated with the Belt Supergroup by Miller and Clark (1975), Miller (1974a, 1974b), and Miller and Whipple (1989). The bulk of the Belt Supergroup is exposed in southeastern British Columbia, northern Idaho, and western Montana. The Striped Peak (Yms_s), Wallace (Yms_{wu}, Yms_{wl}), St. Regis (Yms_{sr}), Revett (Yms_r), Burke (Yms_b), and Prichard (Yms_p) Formations of the Belt Supergroup are present in the Colville 1:100,000-scale quadrangle. Rocks of the Belt Supergroup are less deformed than rocks of the Priest River Group and have not been affected by deformation associated with the Kootenay arc. The rocks generally have been thermally upgraded due to the concentration of intrusive activity in the area where these rocks are exposed.

Yms_s

Striped Peak Formation--Noticeably recrystallized medium-gray siltite and quartzite and dark-gray argillite. Much of unit has a pink cast. Beds range in thickness from thinly laminated argillite to medium- to thick-bedded siltite and quartzite. The formation displays shallow-water features (mud cracks, mud-chip breccia, cross lamination, and ripple marks). The unit is approximately 304 m thick (Miller, 1974a). It is poorly exposed on the west flank of Ruby Mountain in the southeastern part of the quadrangle.

Yms_{wu}

Wallace Formation (upper unit)--Chiefly argillite that is exposed with siltite, andalusite schist, and phyllite on Ruby Mountain. This unit is metamorphosed to andalusite-cordierite-muscovite-biotite-quartz-oligoclase hornfels or schist. Approximately 152 m above the contact with the lower part of the formation, a 91-m-thick section of thin-bedded, tan and gray recrystallized dolomite with thin siliceous layers along bedding planes is interbedded with the argillite. Most sedimentary structures have been destroyed by metamorphism (Miller, 1974b).

Yms_{wl}

Wallace Formation (lower unit)--Pale green and white calc-silicate, hornfels, quartzite, and siltite. The rock commonly has a striped appearance. The typical mineral assemblage is tremolite (or actinolite)-quartz-plagioclase ± biotite (Miller, 1974a). The unit commonly has the irregular bedding characteristic of the lower part of the Wallace Formation, but generally has thinner laminae. The unit is approximately 550 m thick in the Chewelah 1:100,000-scale quadrangle (Miller, 1974b).

Yms_{sr}

St Regis Formation--Dark-red to maroon, locally white, green, or gray, thin- to medium-bedded siltite and thinly laminated argillite, with minor medium- to thick-bedded quartzite. Most of the unit consists of siltite beds 6 cm to 16 cm thick. The formation characteristically displays ripple marks, mud cracks, and mud-chip breccia and is estimated to be 300 m thick in the Chewelah 1:100,000-scale quadrangle to the south (Miller, 1974a).

Yms_{r}

Revett Formation--Thin- to very thick bedded, white to light-gray or tan, fine-grained quartzite. Numerous quartz-rich siltite beds are restricted to a 60- to 150-m zone near the middle and to the gradational upper and lower contacts; argillite beds are thin and sparse. The upper unit is approximately 700 m to 800 m thick. The contact with the St. Regis Formation is gradational; the rocks grade from the medium- to thin-beded siltite, quartzite, and argillite of the St. Regis Formation through a stratigraphic interval of about 30 m to 60 m (Miller, 1974a).

Yms_{b}

Burke Formation--Medium- to thick-bedded, medium- to light-gray siltite interbedded with medium- to light-gray silty quartzite and quartzite; schistose in many places. This unit is estimated to be 790 m to 1,020 m thick in the Chewelah 1:100,000-scale quadrangle to the south (Miller, 1974a). The contact with the Revett Formation is gradational.

Yms_{p}

Prichard Formation--Medium- to dark-gray, thin- to medium-bedded siltite, argillite, and light-gray, medium- to thick-bedded, fine-grained, silty quartzite, and quartzite. The siltite contains pyrite and pyrrhotite, is well laminated, and displays fine, planar, graded couplets of siltite and silty quartzite (rhythmites). The thickness was estimated at 5,200 m in the Chewelah 1:100,000-scale quadrangle to the south (Miller, 1974a). Near the Boulder Mountain pluton of the granodiorite of Hall Creek, the formation is noticeably recrystallized; andalusite is commonly developed in argillaceous layers (Miller, 1983). It is cut by Purcell sills along Indian Creek (F. K. Miller, USGS, written commun., 1987).

Intrusive Rocks

Tertiary Intrusive Rocks

Eii,

Mafic dikes (Eocene)--Fine-grained, commonly porphyritic and vesicular, medium-gray to gray-brown lamprophyre to augite biotite monzonite. The dikes locally contain phenocrysts of monoclinic pyroxene, plagioclase, biotite, hornblende, and olivine. Only the larger dikes and dike swarms are shown on Plate 1.

Lamprophyre dikes that cut the Spirit pluton were studied by Todd (1973). One type of lamprophyre dike contains phenocrysts of augite, hornblende, and subhedral zoned plagioclase (An_{46} near the core, An_{32} in the rim) in a fine-grained matrix that includes hornblende, augite, biotite, opaque minerals, magnetite, and plagioclase. A second type contains phenocrysts of subhedral augite, subhedral, zoned plagioclase (An_{60} at the core, An_{45} in the rim), and subhedral biotite in a matrix of plagioclase, biotite, augite, opaque minerals, magnetite, and rare quartz and orthoclase (Todd, 1973).

These mafic dikes also cut the Sheppard Granite, the O'Brien Creek Formation, and the Sanpoil Volcanics (near Colville). On the east side of the Columbia River, 3.2 km south of the international border, a lamprophyre dike, part of a swarm cutting the Sheppard Granite, yielded a hornblende K-Ar age of 53.0 Ma (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977). Yates and Engels (1968) suggest that the lamprophyre dikes are mineralogically and chemically consanguineous with the Coryell intrusive rocks and the shonkinite of the Williams Lake area. Bradshaw (1964) suggests that the dikes are contemporaneous with or younger than the Sanpoil Volcanics.

Eis_c,

Coryell intrusive rocks (Eocene)--Reddish to pale-buff, medium- to coarse-grained, inequigranular, locally porphyritic syenite, monzonite, and shonkinite present as intrusive bodies and as porphyritic syenitic dikes shown by the symbol in the northwest part of quadrangle. White and pink microperthite and orthoclase are the most abundant minerals, but the rocks contain some plagioclase. Mafic minerals generally make up from 1 to 10 percent of the rock. Accessory minerals include apatite, sphene, zircon, magnetite, and allanite. The unit generally contains 52 to 64 percent SiO_2, $Na_2O + K_2O$ equal to 12 percent, and no feldspathoid minerals (Little, 1982). Granite is present locally where quartz content exceeds 10 percent. These rocks were named by Daly (1912) for exposures in British Columbia.

Dikes of the Coryell intrusive rocks cut the upper Cretaceous Sophie Mountain Formation. K-Ar biotite ages obtained by Baadsgaard and others (1961) from rocks in southern British Columbia are 54 and 58 Ma. Little (1982), however, considers these ages too old because of the genetic relations between the Coryell intrusive rocks and the middle Eocene rocks. Yates and Engels (1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977) obtained K-Ar biotite ages of 51.7 ± 1.5 Ma and 52.0 ± 1.5 Ma from satellite syenite dikes near Big Sheep Creek and on Flagstaff Mountain, respectively. A zircon U/Pb age of 51.1 ± 0.5 Ma was obtained by Carr and Parkinson (1989) from the Granby River area in southern British Columbia, 40 km north of the international border. The Coryell unit is considered to be genetically related to the Sanpoil Volcanics and correlative with the monzonite of Long Alec Creek in the Curlew quadrangle (Parker and Calkins, 1964), and with the quartz monzonite on the east side of the Sherman fault in the Republic quadrangle (Muessig, 1967).

Eia_s

Sheppard Granite (Eocene)--Leucocratic, white or pink, medium- to fine-grained, equigranular granite and syenite present in the northwest part of the map area. The granite contains myrmekite (49%), perthitic orthoclase (21%), altered albite (An_{0-10}), K-feldspar, quartz, chlorite, and biotite. Accessory minerals include magnetite, zircon, and apatite. At the type section, in Canada, the rock contains 73 percent SiO_2 and 8 percent combined Na_2O and K_2O (Little, 1982).

The granite has had little thermal effect on surrounding rocks. Cataclastic deformation is suggested by bent albite lamellae and streaks of mylonite. The strike of cleavage and foliation is generally to the northeast; dips are to the southeast (Yates, 1976).

The Sheppard Granite was named by Daly (1912) for exposures in Sheppard Creek, a western tributary to the Columbia River in British Columbia. Dikes of this granite intrude the Upper Cretaceous Sophie Mountain Formation. The granite is cut by lamprophyre dikes that have been dated at 53.0 ± 1.5 Ma (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977) and is thought to be a phase of the Coryell intrusive rocks (Little, 1982).

Eik

Shonkinite (Eocene)--Gray-green, fine-grained shonkinite that is present as dikes and sills in the Williams Lake area. It contains aggregates of euhedral sanidine (30-35%), chlorite and muscovite (40-50%), pyroxene (10%), olivine (5%), opaque minerals (5-10%), and less than 1 percent each of quartz, apatite, zircon, diopside, magnetite, glass, and plagioclase. Sanidine forms large poikilitic crystals that make up 1 to 2 percent of the rock, the remainder forming fine-grained laths; all sanidine has been sericitized and chloritized (Duncan, 1982; Laskowski, 1982). The unit intrudes the O'Brien Creek Formation and andesite flows (Eva). A K-Ar age on biotite is 51.0 ± 1.5 Ma from the Williams Lake area (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

Eida, —┼┼┼—

Hypabyssal dikes (Eocene)--Light- to medium-gray, porphyritic, hornblende-biotite- and biotite-bearing dacite dikes. Phenocrysts make up 25 to 40 percent of the rock and consist of plagioclase ± hornblende ± biotite ± pyroxene; quartz and sanidine are rare. The fine-grained to glassy matrix consists of quartz and plagioclase. Similar hornblende-bearing dikes in the Republic graben are thought to be feeders to the Sanpoil Volcanics (Moye, 1984).

$Eigd_r$

Undivided granitic rocks near Hooknose Ridge--

> "Occurs as two small stocks and one dike-form body in Hooknose Ridge area. Western body is medium- to fine-grained hornblende-biotite granodiorite and coarse grained poikilitic hornblende gabbro. Both have relatively low color index for this type of rock. Fine-grained dikes associated with granodiorite. Eastern stock is more mafic. Medium- to fine-grained hornblende-biotite granodiorite most common rock type, but also minor fine-grained porphyritic hornblende tonalite. Former distinguished by blocky 5 mm long potassium feldspar crystals in equigranular groundmass of light and dark minerals"

(Burmester and Miller, 1983, p. 3). Yates (1976) suggested the rocks were Eocene in age. Dikes of this unit were intruded along the Russian Creek fault.

Eir,

Rhyolite granophyre (Eocene)--Leucocratic, fine-grained dikes that have granophyric texture and rhyolitic composition (Yates, 1971); includes dikes and small bodies of various orientations in the northwest part of the map area.

Eib

Diorite (Eocene)--Brown-weathering, coarse-grained dikes in Echo Valley and on Echo Mountain. Plagioclase (0.5-1 mm) is the dominant mineral and is generally intensely sericitized. The diorite locally contains as much as 15 percent chlorite; accessory minerals include pyrite, hematite, and zeolites and lesser amounts of quartz, orthoclase, biotite, and calcite in the groundmass (Hogge, 1982). The unit contains less than 50 percent SiO_2 and 8 percent combined K_2O and Na_2O (Mills, 1985). It intrudes Permian and Carboniferous-Ordovician metasedimentary and metavolcanic rocks and is sheared by the fault that separates the Permian metasedimentary rocks and Carboniferous-Ordovician greenstone (COmv) on Echo Mountain. Mills (1985) presumed that this unit is Tertiary; it does not appear to have been metamorphosed (K. L. Stoffel, DGER, oral commun., 1989).

Cretaceous Intrusive Rocks

Intrusive rocks in the lower plate of the Newport fault (west of the Pend Oreille River)

Kia_s

Starvation Flat Quartz Monzonite (Clark and Miller, 1968) (Cretaceous)--Light-gray, medium- to coarse-grained, hornblende-biotite monzogranite; ranges from granodiorite to monzogranite (redefined following IUGS igneous rock classification of Streckeisen, 1973). Plagioclase (An_{25}) is the most abundant mineral. Orthoclase is interstitial to other minerals; perthitic intergrowths are common. Anhedral quartz is present in interstices of plagioclase and mafic minerals. Mafic minerals average 13 percent of the rock; the hornblende to biotite ratio averages 0.7. Accessory minerals include sphene, zircon, apatite, and opaque minerals. K-Ar ages are 99 ± 3 Ma (biotite) and 100 ± 3 Ma (hornblende) (Miller and Clark, 1975; recalculated using IUGS constants, Steiger and Jaeger, 1977) and 97.8 ± 2.9 Ma on biotite from samples in the Chewelah 1:100,000-scale quadrangle (Miller and Engels, 1975). The monzonite is present near White Mud Lake; the unit was named by Clark and Miller (1968) for exposures in the Chewelah 1:100,000-scale quadrangle.

Kia_n

Biotite granite near Narcisse Creek (Cretaceous)--Leucocratic, medium- to coarse-grained, biotite granodiorite to monzogranite that contains pink and white microcline phenocrysts as much as 7 cm long (Miller and Clark, 1975), euhedral biotite, subhedral to euhedral plagioclase, and anhedral quartz; accessory minerals include magnetite, sphene, apatite, zircon, and pyrite. Biotite content increases to the northeast. The unit is foliated at its eastern contact.

This granite crops out between the middle fork of Mill Creek and the Little Pend Oreille River at the south edge of the quadrangle. The contact metamorphic halo is approximately 1.5 km wide near Hande Creek where calc-silicate rock and amphibolite are present. Contacts with other intrusive rocks are unclear. Miller and Clark (1975) suggest that this body has a groundmass texture similar to that of the Starvation Flat Quartz Monzonite and that the two plutons may be genetically related. However, the Starvation Flat unit contains hornblende and no microcline (Miller and Clark, 1975).

A K-Ar age on biotite in this biotite granite is 104.5 ± 2.9 Ma (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

Kiat

Undivided two-mica granitic rocks (Cretaceous)--Leucocratic, medium- to coarse-grained porphyritic, muscovite-biotite granodiorite. Plagioclase (average An_{22}) is the most abundant mineral; zoned crystals contain epidote. Microcline averages as much as 11 percent of the rock; phenocrysts, where present, are as much as 2.5 cm long. Quartz is pale gray-violet and commonly forms glomerocrysts. Myrmekite intergrowths are common. Biotite and muscovite average 15 percent of the rock and have a ratio that ranges from 3:1 and 10:1. Micas are euhedral and form clusters, commonly rim quartz or feldspars, and show no sign of alteration. Accessory minerals include allanite, apatite, garnet, magnetite, zircon, and tourmaline (Miller and Clark, 1975). The granitic rocks are intruded by alaskite pegmatite and aplite dikes, which in some places make up 50 percent of the unit. Near Flodelle Creek the rocks are fine to medium grained, intensely weathered, and generally represented by grus. Inclusions of epidote in plagioclase and minor muscovite in K-feldspar in the Chewelah 1:100,000-scale quadrangle led Miller and Clark (1975) to suggest that these rocks had been metamorphosed.

Muscovite-biotite intrusive rocks in the south-central part of the Colville quadrangle are contiguous with rocks mapped as Phillips Lake Granodiorite by Miller and Clark (1975) on the Chewelah 1:100,000-scale quadrangle. Miller and Clark (1975, p. 55) indicated that intrusive rocks near Huckleberry Mountain are "modally, texturally, and mineralogically identical with the Phillips Lake Granodiorite." Most of the undivided muscovite-biotite granitic rocks are probably part of the same body as the Phillips Lake Granodiorite.

K-Ar ages reflect the uplift and cooling history of the Priest River complex, of which these rocks form the western part (Harms, 1982). Ages are reset proportional to the proximity to the Newport fault zone (Miller and Engels, 1975). The Cretaceous age assignment is based on decreasing discordance of K-Ar apparent ages for co-existing muscovite and biotite approaching a near-concordant mineral pair age of 93 Ma on biotite and 98 Ma on muscovite near the western edge of the unit (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977). On Huckleberry Mountain biotite yielded a K-Ar age of 94.5 ± 3.0 Ma, and muscovite from a pegmatite yielded a K-Ar age of 101.5 ± 3.2 Ma; these ages may record some argon loss in the biotite (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

$Kiaa_{sp}$, Kia_{sp}, Kia_{spb}

Spirit pluton (Cretaceous)--East-west elongate, undeformed, biotite quartz monzonite, granite, and monzogranite. The pluton was mapped as granodiorite by Yates (1964, 1970) and redefined as a quartz monzonite to monzogranite by Todd (1973) following the IUGS igneous rock classification (Streckeisen, 1973). The pluton is thought to be a magmatic differentiate with two phases: a central porphyritic biotite granite (Kia_{sp}), and a nonporphyritic biotite quartz monzonite border phase (Kia_{spb}) (Yates, 1964; Yates and Engels, 1968; Todd, 1973). A small late-phase alaskitic body ($Kiaa_{sp}$) is also present. A biotite-hornblende quartz diorite and gabbro was thought by Yates (1964) and Yates and Engels (1968) to be the oldest phase of the pluton. However, petrographic evidence led Todd (1973) to conclude that this rock, at the eastern margin of the pluton, was in fact Precambrian amphibolite intruded and partially assimilated by the porphyritic monzogranite (Kia_{sp}). The pluton is intruded by lamprophyre dikes, mineralized quartz veins, aplite, and pegmatite dikes (Todd, 1973).

The pluton has sharp intrusive contacts with border rocks. Contact metamorphism has affected all metasedimentary and metavolcanic rocks along its border. Todd (1973) assigned the inner metamorphic aureole of the Spirit pluton to the hornblende-hornfels facies. Carbonate rocks of the Metaline Formation 3 m or closer to the pluton contain an assemblage of diopside, calcite, wollastonite ± idocrase ± forsterite(?) ± garnet; at distances of more than 3 m and less than 100 m, a common assemblage in the Metaline is tremolite, diopside, and quartz. At distances of 100 m to 600 m from the border of the pluton the assemblage of tremolite, calcite, and quartz is common in these carbonate rocks. Pelitic Precambrian rocks on Huckleberry Mountain 3 m or closer to the border of the pluton contain an assemblage of quartz, biotite, muscovite ± cordierite ± andalusite.

Biotite from the nonporphyritic border phase at the west end of the pluton gave a K-Ar age of 102 ± 2.8 Ma. Hornblende from the quartz diorite, which is thought by Todd (1973) to be an assimilated amphibolite, gave an age of 96.3 ± 3.0 Ma (Yates and Engels, 1968; recalculated using current IUGS constants, Steiger and Jaeger, 1977). Nearly west-trending structures probably controlled the emplacement of the pluton; the pluton clearly crosscuts folding (Yates, 1976).

$Kiaa_{sp}$

Alaskite--Light-gray, fine- to medium-grained (0.25-1.0 mm), with nearly equal proportions of interlocking quartz and white anhedral orthoclase. Biotite constitutes less than 1 percent of the rock. Leucoxene is present as an alteration product of rare garnets. Alaskite is present in two masses less than 80 m long and transects all other parts of the pluton (Todd, 1973).

Kia_{spk}

Biotite granite--Light-gray, very coarse to coarse-grained porphyritic, homogeneous biotite monzogranite and granite containing nearly equal proportions of quartz, white and pink K-feldspars, and biotite. Much of the orthoclase is perthitic; plagioclase (An_{40-20}) is both zoned and unzoned. Accessory minerals include sphene, allanite, penninite, zircon, and opaque minerals. There is a gradational contact with biotite quartz monzonite (Kia_{spb}) (Todd, 1973).

Kia_{spb}

Biotite quartz monzonite--Light-gray, nonporphyritic, very coarse to coarse-grained, equigranular biotite quartz monzonite that is generally restricted to the border phase. Quartz is anhedral; K-feldspar is orthoclase. Plagioclase is zoned and unzoned; cores average An_{47}. Myrmekite is common around plagioclase. Biotite forms subhedral books, and it is foliated near the borders of the pluton. Accessory minerals include apatite, sphene, magnetite, hematite, allanite, zircon, and hornblende (Todd, 1973).

Intrusive rocks in the upper plate of the Newport fault (generally east of the Pend Oreille River)

Intrusive rocks in the upper plate of the Newport fault generally are discrete plutons that have narrow metamorphic halos and are commonly zoned. Rocks termed "two mica" locally contain 1 percent or less primary muscovite and are characterized by the absence of sphene. They have a combined Fe, Mg, and Ca oxide average of 5 percent or less (Miller, 1980).

$Kiat_{gp}$

Monzogranite of Granite Pass (Cretaceous)--Leucocratic (color index 0-3), medium- to coarse-grained, nonporphyritic muscovite-monzogranite and muscovite-biotite monzogranite. The rock contains microcline and albite (An_3) and approximately 6 percent muscovite that is in places intergrown with biotite (Miller, 1983). The pluton is apparently zoned; sparse biotite is restricted to the outer 0.5 km of the pluton and is absent from the center. This distinct pluton has well-defined contacts, has no fabric, and intrudes all units of the Priest River Group (Miller, 1983). Muscovite from the southwest part of the pluton yielded a K-Ar age of 97.8 ± 2.9 Ma, which represents a minimum age (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

$Kiaa_m$

Monzogranite of Middle Creek (Cretaceous)--Leucocratic, medium- to fine-grained monzogranite. The texture is varied; alaskite, aplite, and pegmatite are common (F. K. Miller, USGS, written commun., 1988). The monzonite contains as much as 3 percent biotite and 10 percent muscovite. K-feldspar is orthoclase or untwinned microcline and occurs with plagioclase and quartz in approximately equal proportions. Accessory minerals include apatite, zircon, and garnet. Molybdenite is present in fractures. The uranium content is higher than the average in other plutons in the region. This unit intrudes the Gleason Mountain monzogranite. It is poorly exposed and deeply weathered (Castor and others, 1982). It may actually be numerous closely-spaced dikes and pods of leucocratic rock which intrude the Galena Point Granodiorite rather than a discrete pluton (F. K. Miller, USGS. written commun., 1988).

$Kiat_{hm}$

Monzogranite of Hungry Mountain (Cretaceous)--Leucocratic (color index 7), light-gray, medium- to coarse-grained, biotite quartz monzonite. Zoned plagioclase averages An_{20}. Quartz is present as large, gray crystals or crystal aggregates. Phenocrysts of microcline, 0.5 to 1.5 cm long, form irregular clots and locally comprise as much as 60 percent of the unit. Biotite is the only mafic mineral; muscovite nowhere exceeds 1 percent and forms smaller crystals than other minerals. Accessory minerals include zircon, apatite, allanite, and opaque minerals (Miller, 1982a). Castor and others (1982) reported faint primary foliation composed of trains of equant quartz grains. Miller (1982a) describes the pluton as directionless. Castor and others (1982) suggest that the pluton is cut by the monzogranite of Gleason Mountain, whereas Miller (1982a) indicates that it grades into the Gleason Mountain unit through a decrease in grain size and phenocryst concentration. This deeply weathered pluton intrudes the Galena Point Granodiorite, but contact relations are unclear (Miller, 1982a). A K-Ar ages on biotite is 92.3 ± 2.7 Ma and on muscovite is 96.7 ± 2.8 Ma (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977). The pluton has the highest background uranium content of any plutonic rock in the quadrangle (Castor and others, 1982).

Kiat$_{gm}$

Monzogranite of Gleason Mountain (Cretaceous)--Leucocratic (color index 7), medium-grained, locally fine- or coarse-grained, equigranular to seriate, muscovite-biotite monzogranite. The pluton locally contains sparse and irregularly distributed microcline phenocrysts as much as 4 cm long. Plagioclase content averages An_{18}. Muscovite generally constitutes less than 1 percent of the rock; the biotite to muscovite ratio varies, but the monzogranite contains more biotite than muscovite. Biotite is the only mafic mineral. Chemically, modally, and mineralogically this rocks is very similar to the monzogranite at Hungry Mountain; however, texturally the two units differ (Miller, 1982a). Castor and others (1982), however, suggested that the pluton cuts the Hungry Mountain pluton and is cut by the monzonite of Middle Creek. Miller (1982a) notes that it appears to intrude the Galena Point Granodiorite, but that contacts are poorly exposed and ambiguous.

Kia$_{l}$

Granodiorite of Le Clerc Creek (Cretaceous)--Leucocratic, medium-grained hornblende-biotite granodiorite. Contact relations with the granodiorite of Bunchgrass Meadows (Kigd$_{bg}$) are uncertain (F. K. Miller, USGS, written commun., 1988).

Kiat$_{m}$

Granodiorite of Molybdenite Mountain (Cretaceous)--Leucocratic, coarse-grained, porphyritic, foliated, muscovite-biotite granodiorite. Quartz is light gray and forms clusters of rounded, granular crystals that are stretched parallel to biotite. The average biotite:muscovite ratio is approximately 5:1. The muscovite content increases and the biotite:muscovite ratio decreases toward the center of the body. Muscovite and biotite are subhedral and similar in size and mode of occurrence. Concordant K-Ar ages are 103 ± 3.0 Ma (biotite) and 103 ± 3.0 Ma (muscovite) (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977). This unit is cut by alaskite pegmatite dikes, and it intrudes rocks of the Windermere and Priest River Groups. Metamorphic effects extend approximately 1 km from the contact.

Hall Mountain Intrusive Rocks

Kiat$_{hl}$, Kiat$_{hp}$, Kiat$_{ht}$, Kiat$_{hh}$, Kiat$_{h}$, Kiat$_{ho}$, Kiat$_{hb}$

Hall Mountain intrusive rocks (Cretaceous)--Chiefly leucocratic, muscovite-biotite granodiorite, but ranges from tonalite to calcic monzogranite (Miller and Frisken, 1984). Muscovite in the granodiorite of Hall Mountain is spatially associated with biotite and appears to be primary, although it postdates the biotite. Biotite is generally brown or olive green. K-feldspar is microcline that contains inclusions of fairly large plagioclase and, less commonly, biotite crystals. Accessory minerals include epidote, clinozoisite, allanite, zircon, apatite, rutile, and minor opaque minerals (Miller and Frisken, 1984; Miller, 1983).

This group of distinct plutons, which has narrow contact metamorphic aureoles and chilled margins of finer grained rock, is generally thought to be higher level plutons. They are genetically related to the granodiorite of Reeder Creek (Kiat$_{r}$).

$Kiat_{hl}$

Loop Creek pluton of the granodiorite of Hall Mountain--A small, poorly exposed body in the southeast corner of the map area that extends to the west across the Pend Oreille River to the base of Ruby Mountain. It contains sparse muscovite and locally is coarser than most Hall Mountain-type rock. The coarser grained parts resemble the Reeder Creek pluton on the west side of Priest Lake in Idaho. In thin section, medium- to coarse-grained felsic minerals are surrounded by thin rims of very fine grained feldspar, quartz, and mica, suggesting the rock may have been quenched. The border zone at the base of Ruby Mountain is fine grained. Quartz veins are ubiquitous and locally abundant. Pyrite is common in much of this pluton, even where no alteration is apparent (F. K. Miller, USGS, written commun., 1988).

$Kiat_{hp}$

Paupac Creek pluton of the granodiorite of Hall Mountain (Cretaceous)--Leucocratic, light-gray to light-brown-gray, medium- to coarse-grained, equigranular muscovite-biotite quartz monzonite that contains white K-feldspar phenocrysts. Biotite and quartz are highly foliated or lineated along the borders of the pluton; the pluton is progressively less foliated toward its interior (Miller and Frisken, 1984). Muscovite is restricted to the interior of the pluton. The texture is finer grained at the contact than at the interior (F. K. Miller, USGS, oral commun., 1988). This pluton intrudes the Leola Volcanics to the north.

$Kiat_{ht}$

Tillicum Peak pluton of the granodiorite of Hall Mountain (Cretaceous)--Leucocratic (color index 7) granodiorite; more leucocratic than other plutons of the Hall Mountain type. The biotite:muscovite ratio is about 3:1. The pluton contains numerous micro-shears that increase in number toward the western edge of the pluton. Shears are visible in thin section as trains of broken and rehealed quartz and feldspar grains, and broken, disaggregated, and partially recrystallized mica. The west side of the pluton contains numerous closely spaced quartz veins and local sericitic alteration; pyrite is locally abundant. Panned concentrates of sediments from streams draining the east side of the pluton contain anomalously high amounts of W, Bi, Ag, Mo, and Pb (Miller and Frisken, 1984).

$Kiat_{hh}$

Harvey Creek pluton of the granodiorite of Hall Mountain (Cretaceous)-- Small dike-like body in the drainage of the South Fork of Granite Creek that is similar in composition to other rocks of the granodiorite of Hall Mountain, but are finer grained. Contact relations are hidden by Quaternary sediments. A retrograde contact metamorphic assemblage (pyrite, magnetite, brucite, and antigorite in a fine-grained mixture of calcite and dolomite) is present along the south side of the pluton, where country rock is impure Precambrian carbonate. Most of this body shows pervasive alteration, particularly in the northern part of the body; molybdenite is present in quartz veins. A K-Ar age on apparently unaltered muscovite is 96.4 Ma (Miller and Theodore, 1982).

$Kiat_h$

Hall Mountain pluton of the granodiorite of Hall Mountain--Leucocratic (color index 9) granodiorite. Plagioclase ranges from An_{25} to An_{35}, but the average composition is closer to the calcic end. K-feldspar is microcline. Quartz forms irregularly shaped crystals about 4 mm across, which are commonly aggregates of small broken, and rehealed crystals. Biotite is the only mafic mineral; the biotite:muscovite ratio averages 10:1. Accessory minerals include epidote, clinozoisite, allanite, zircon, apatite, rutile, and a minor amount of opaque minerals (Miller, 1983). The pluton is lineated to foliated in its outer part; the foliation appears to be primary. The width of the contact metamorphic halo rarely exceeds 20 m. The northern part of pluton is relatively unaltered; the southern part is highly sericitized and cut by quartz veinlets that contain disseminated pyrite (Miller, 1983). Biotite from the northernmost part of the pluton yielded a K-Ar age of 99.0 ± 3.0 Ma (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977)

$Kiat_{ho}$

Orwig Hump pluton of the granodiorite of Hall Mountain--Muscovite-biotite granodiorite; color index 15, making this one of the most mafic plutons of the Hall Mountain type. The ratio of biotite to muscovite is 5:1. Plagioclase composition averages about An_{33}; the K-feldspar is microcline. Rock at the margins of the pluton is fine grained and includes quartz phenocrysts (F. K. Miller, USGS, written commun., 1988). A K-Ar age from biotite is 86.7 ± 2.5 Ma (Miller and Engels, 1975, recalculated using current IUGS constants, Steiger and Jaeger, 1977).

$Kiat_{hb}$

Boulder Mountain pluton of the granodiorite of Hall Mountain (Miller, 1982a) (Cretaceous)--Leucocratic (color index 13), fine-grained, seriate, biotite-muscovite(?) granodiorite. K-feldspar is generally finer grained than other minerals and is locally poikilitic. Plagioclase composition is An_{30-35}. Quartz forms 1-cm-wide phenocrysts near the margin; elsewhere, it is fine grained. The pluton contains minor muscovite (Miller, 1982a). It intrudes the Prichard Formation; chill textures are found at the margins of the pluton. Numerous large quartz bodies and slightly anomalous amounts of molybdenite are present in the southern part of pluton; alteration is extensive in the center of the body (Miller and Theodore, 1982).

$Kiat_r$

Granodiorite of Reeder Creek (Cretaceous)--Leucocratic (color index 11), medium-grained, porphyritic, muscovite-biotite granodiorite. Textures and composition are uniform. All K-feldspar is microcline; plagioclase averages An_{30}. Quartz is gray violet and forms both large and small crystals, giving the rock a seriate appearance. Biotite is anhedral. The granodiorite contains approximately 0.5 percent fine-grained muscovite. Accessory minerals include allanite, epidote, zircon, apatite, and opaque minerals. The pluton intrudes the Prichard Formation and granodiorite of Priest Lake; its contact with the Galena Point Granodiorite is not exposed (Miller, 1982a). This unit is petrographically, mineralogically, and modally similar to Hall Mountain-type intrusive rocks, except that it is coarser grained and shows none of the shallow-level characteristics of the Hall Mountain intrusive rocks (Miller and Theodore, 1982).

Kia_g

Galena Point Granodiorite (Miller, 1974a) (Cretaceous)--Leucocratic, porphyritic, biotite granodiorite to monzogranite. Euhedral K-feldspar is pink and white; oligoclase is zoned. Biotite is the only mafic mineral and makes up 12 percent of the rock. Accessory minerals include zircon, apatite, magnetite, sphene, allanite, opaque minerals, and trace amounts of hornblende and muscovite (Miller, 1974a). This unit appears to be intruded by the Hungry Mountain pluton and Gleason Mountain monzogranite, but contact relations are ambiguous (Miller, 1982a). A contact metamorphic aureole extends as much as 1.5 km from mapped contacts. The granodiorite was named by Miller (1974a) for exposures in the Chewelah 1:100,000-scale quadrangle. A K-Ar age on biotite is 100.7 ± 3.2 Ma and is considered a close approximation of the age of emplacement (Miller, 1974a; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

$Kigd_y$

Granodiorite of Yocum Lake (Cretaceous)--Leucocratic, light-gray, medium- to coarse-grained, porphyritic, hornblende-biotite granodiorite that contains pink and white K-feldspar phenocrysts. Mafic minerals comprise 8 to 15 percent of the rock; the biotite:hornblende ratio is from 5:1 to 10:1. Accessory minerals include sphene, magnetite, and trace amounts of zircon and apatite (Castor and others, 1982). Concordant K-Ar ages are 100.3 ± 2.9 Ma (biotite) and 99.8 ± 2.9 Ma (hornblende) (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977). A similar body on the west side of the Pend Oreille River yielded a biotite K-Ar age of 99.1 ± 2.9 Ma (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977).

$Kigd_{bg}$

Granodiorite of Bunchgrass Meadows (Cretaceous)--Medium-grained, nonporphyritic, hornblende-biotite granodiorite. Color index, mineralogy, and texture are similar to those in the granodiorite of Sema Meadows. Mafic inclusions are especially abundant in the western part of this pluton. It is probably genetically related to granodiorite of Sema Meadows (F. K. Miller, USGS, written commun., 1988).

$Kigd_{sm}$

Granodiorite of Sema Meadows (Cretaceous)--Leucocratic (color index 18), porphyritic, medium- to coarse-grained hornblende-biotite granodiorite. Phenocrysts are pink microcline averaging 2.5 cm in length. Abundant macroscopic sphene is present throughout the pluton. Other accessory minerals include apatite, zircon, and opaque minerals; epidote is present but is probably secondary. Mafic inclusions are common. The composition and texture are varied on an outcrop scale in many parts of the pluton. In most places the unit is structureless, but locally it has subtle lineation. This rock appears to grade into the granodiorite of Bunchgrass Meadows by a decrease in phenocrysts. The age assignment is based on similarities to nearby plutons of Cretaceous age (F. K. Miller, USGS, written commun., 1988).

$Kigd_{pl}$

Granodiorite of Priest Lake (Miller, 1982a) (Cretaceous)--Medium- to coarse-grained, equigranular to seriate, hornblende-biotite granodiorite; color index 16. Only a few small outcrops are present in the quadrangle, north of Kalispell Creek; the main body of this pluton is east of the map area, in Idaho.

Zoned plagioclase averages An_{30}. K-feldspar is microperthite and nonperthitic orthoclase and occupies interstices between other minerals. Approximately equal amounts of hornblende and biotite are present; hornblende commonly is found as 1-cm-long stubby prisms. Accessory minerals include sphene, zircon, apatite, allanite, epidote, and opaque minerals. Some coarse- grained to pegmatitic mafic masses are present at the margins of pluton, especially at its contact with the granodiorite of Reeder Creek (Miller, 1982a).

$Kigd_{mc}$

Mill Creek granodiorite (Cretaceous)--Fine-grained, hornblende-biotite granodiorite to quartz diorite. Plagioclase is the most abundant mineral. The granodiorite includes medium-grained plagioclase phenocrysts. Mafic minerals make up as much as 30 percent of rock; the biotite:hornblende ratio is 2:1 to 1:1. Accessory minerals include magnetite and sphene. The pluton contains abundant inclusions of mafic and leucocratic rocks. Hornblende from this pluton yielded a K-Ar age of 104.2 Ma and coexisting biotite age of 100.4 Ma (R. Fleck, USGS, written commun. to F. K. Miller, USGS, 1989).

Kig_s

Monzogranite of Sand Creek (Cretaceous)--Leucocratic (color index 8), medium- to coarse-grained, porphyritic, biotite monzogranite. K-feldspar is present as abundant pink microperthitic orthoclase phenocrysts and as orthoclase, with some microcline in the ground mass. Plagioclase is An_{30}; quartz forms smokey-gray, anhedral crystals that average 1 cm in length. Biotite is the only mafic mineral and is slightly chloritized. Accessory minerals include abundant allanite, magnetite, zircon, and apatite (Burmester and Miller, 1983). The unit is slightly seriate and finer grained at its borders. It has a K-Ar age of 98.7 ± 3.0 Ma (Miller and Engels, 1975; recalculated using current IUGS constants, Steiger and Jaeger, 1977). Burmester and Miller (1983) suggest that the composition and texture of this pluton may indicate that it is the differentiated high level part of the Spirit pluton that is exposed on the lower plate of the Newport fault.

Mesozoic Mafic Intrusive Rocks

Jib

Basic intrusions (Jurassic)--Medium-grained, porphyritic diorite. Plagioclase is the most abundant mineral and is commonly twinned. Hornblende and biotite are chloritized and appear to be interstitial to the plagioclase. The unit is generally sheared, and it intrudes the Rossland Group and Carboniferous-Devonian metasedimentary rocks in the northwest part of the map area. It was assigned a Jurassic age by Yates (1964, 1971).

u

Serpentinite (Jurassic?)--Dense, green to chocolate brown serpentinite. This unit contains antigorite with small amounts of chrysotile, as well as approximately 5 percent carbonate minerals in diffuse patches. The body occupies less than 1.5 km² in northwesternmost corner of the map area. Larger northeast- to north-trending bodies of serpentinite crop out to the north in British Columbia and to the west in the Republic 1:100,000-scale quadrangle.

Yates (1971) indicated a Jurassic age for the body, whereas Little (1982) suggested two possible periods of intrusion for similar bodies in British Columbia. Little (1982) reported that the ultrabasic bodies in British Columbia are cut by dikes of the middle Jurassic Nelson Intrusions and cut the lower Jurassic Rossland Group, thus suggesting a Jurassic age of emplacement. Reports of serpentinite fragments in the Rossland agglomerates led Little (1982) to suggest that some ultrabasic rocks were associated with the Permian Mount Roberts Formation, and later emplaced during the Mesozoic tectonic event.

Precambrian Intrusive Rocks

Zib

Intrusive greenstone--Greenstone sills intruded into the Shedroof Conglomerate and the Priest River Group. These are thought by Miller (1983) to be the intrusive equivalent of the Leola Volcanics.

Yib

Purcell Sills--Generally coarse-grained, hornblende-plagioclase gabbro to diorite with minor pyrrhotite, olivine, and quartz in sill-like bodies, from 3 m to more than 100 m thick, that intrude the Prichard Formation in the southeastern corner of the map. Some of the thicker sills are zoned. Sills are generally present more than 1,200 m below the contact with the Burke Formation; the number and thickness of the sills increases down-section. A U/Pb age from zircons in the Crossport C sill, near Bonners Ferry, Idaho, is 1,445 ± 10 Ma; the Crossport C Sill is approximately 2,300 m below the Burke-Prichard contact (Zartman and others, 1982).

Metamorphic Rocks

KYhm

Heterogeneous metamorphic rocks near Flodelle Creek (Precambrian Y to Cretaceous)--Deformed and foliated quartz-feldspar-muscovite schist of probable Precambrian protolith and orthogneiss. Rusty-weathering muscovite-biotite schist and quartzite are irregularly banded with quartz-feldspar-muscovite schist. A body of leucocratic, coarse-grained, epidote-bearing, biotite orthogneiss with weak but pervasive foliation exhibited by biotite and quartz is present near the headwaters of Flodelle Creek (sec. 16, T. 35 N., R. 42 E.). Some K-feldspar phenocrysts are aligned parallel to the fabric in the orthogneiss, as is the fabric in mafic inclusions.

Tectonic Rocks

tz

Tectonic zone (Eocene)--Mylonite and chloritized, brittlely deformed rock and tectonic breccia on the footwall and hanging wall, respectively, of the listric, concave-up Newport fault. The mylonite contains brittlely deformed, porphyroclastic K-feldspar. Quartz is ductilely deformed and generally flattened, recrystallized (to very fine grained aggregates), and stretched. Biotite defines the foliation and, commonly, the lineation; much is altered to chlorite. The composition mimics that of the host intrusive or metamorphic rock. The zone has a gradational contact with rocks in the lower plate, but it has been overprinted by cataclastic deformation (Harms, 1982).

Cataclastic deformation has produced chlorite microbreccia and tectonic mega-breccia. The chlorite microbreccia is 1.5 m to 5 m thick and consists of massive, extremely fine grained, homogeneous, crushed rock with no fabric. Biotite is generally altered to chlorite (Harms, 1982). Intensely brecciated rocks in the hanging wall are found more than a kilometer east of the fault near Ruby Mountain (Miller, 1974b).

The tectonic zone is present in the Pend Oreille River valley (Miller, 1974b; Harms, 1982). Deformation is well developed west of Ruby Mountain and to the south in the Chewelah 1:100,000-scale quadrangle, but it is generally poorly developed or not exposed in the rest of the Colville quadrangle, especially north of State Route (SR) 20 (Tiger Highway). Projection of the Newport fault north of Tiger is tenuous, but the Flume Creek fault, one of the youngest in the Metaline Falls area, is on the projected trace of the Newport fault and possibly the Jumpoff Joe fault (Burmester and Miller, 1983). North of SR 20, the float from the undivided two-mica granitic rocks is strongly foliated along the projection of the structure; rocks of the Spirit pluton are foliated parallel to the trace of the fault in Cedar Creek. North of Cedar Creek only greenschist-facies metasedimentary rocks are present along the trace of the fault, and characteristic features of the fault zone are not present.

Harms (1982, p. ii) writes:

> "The transition from cataclasites to mylonites across the [Newport] fault zone indicates that fault rocks which have been displaced with the hanging wall formed under near-surface conditions of brittle deformation whereas those associated with the footwall formed at mid-crustal levels by ductile deformation...The juxtaposition of supracrustal rock types over those that formed at deeper crustal levels across the Newport Fault [sic] is the result of normal displacement along the listric fault surface..."

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Table 1. Isotopic ages of rocks in the Colville 1:100,000-scale quadrangle

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
				Quaternary				
1	3783	glacio-lacustrine	Qql	NW/4 sec. 4, T. 36 N., R. 43 E.	C^{14}	charcoal	15,000 years	DGER unpublished data
				Eocene Rocks				
				Tuffaceous Rocks				
2	8B	O'Brien Creek Formation	Ec_o	48°48.0'N 117°55.0'W	K-Ar	biotite	41.6 +/- 1.2[a] 41 +/- 1.2[a]	Yates & Engels, 1968[1]
3	9B	O'Brien Creek Formation	Ec_o	48°46.2'N 117°56.6'W	K-Ar	biotite	40.2 +/- 1.3[a]	Yates & Engels, 1968[1]
				Volcanic Flows				
4	10H	Sanpoil Volcanics	Evd_s	48°45.9'N 117°54.9'W	K-Ar recalculation	hornblende	49.8 +/- 1.5 51.1[c]	Yates & Engels, 1968[1]
5	2H	andesite flows	Eva	48°56.4'N 117°55.7'W	K-Ar recalculation	hornblende	50.5 +/- 1.5 51.8[c]	Yates & Engels, 1968[1]
6	1B	andesite flows	Eva	48°57.3'N 117°56.9'W	K-Ar recalculation	biotite	50.4 +/- 1.5 51.7[c]	Yates & Engels, 1968[1]
				Hypabassal Intrusive Rocks				
7	4B	Coryell intrusive rocks	Eis_c	sec. 5, T. 39 N., R. 39 E.	K-Ar recalculation	biotite	50.4 +/- 1.5 51.7[c]	Yates & Engels, 1968[1]
8	3B	Coryell intrusive rocks	Eis_c	sec. 12, T. 40 N., R. 38 E.	K-Ar recalculation	biotite	50.7 +/- 1.5 52.0[c]	Yates & Engels, 1968[1]
9	5H	lamprophyre dike	Eii	near gaging station on Columbia River; SW/4 sec. 16, T. 40 N., R. 41 E.	K-Ar recalculation	hornblende	51.7 +/- 1.5 53.0[c]	Yates & Engels, 1968[1]

Table 1. Isotopic ages of rocks in the Colville 1:100,000-scale quadrangle (continued)

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
10	7B	shonkinite	Eik	48°45.9'N 117°57'W	K-Ar recalculation	biotite	49.7 +/- 1.5 51.0[c]	Yates & Engels, 1968[1]
11	6B	lamprophyre dike	Eii	48°46.6'N 117°55.1'W (unit not shown on map)	K-Ar recalculation	biotite	49.9 +/- 1.5 51.2[c]	Yates & Engels, 1968[1]

<u>Cretaceous Intrusive Rocks</u>

On the lower plate of the Newport fault

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
12		Spirit pluton	Kia_{sp}	48°48'N 117°32'W	Pb-alpha	zircon	145 +/- 2.0	Engels & others, 1976
					Pb-alpha	monazite	120 +/- 15	Engels & others, 1976
13	11B,29	Spirit pluton	Kia_{sp}	48°44'N 117°51'W	K-Ar recalculation	biotite	100 +/- 2.8 102[c]	Yates & Engels, 1968[1]
14	12H	Spirit pluton (quartz diorite; may be partially assimilated Leola Volcanics)		sec. 20, T. 38 N., R. 42 E. (unit not shown on map)	K-Ar recalculation	hornblende	94.0 +/- 3 96.3[c]	Yates & Engels, 1968[1]
15	13 B (27)	Spirit pluton	Kia_{spb}	48°47'N 117°31'W	K-Ar recalculation	biotite	91.0 +/- 3.0 93.3[c]	Yates & Engels, 1968[1]
					K-Ar recalculation	muscovite	96.0 +/- 3.0 98.4[c]	Yates & Engels, 1968[1]
16	14M	undivided two-mica granitic rocks	Kiat	sec. 24, T. 38 N., R. 42 E.	K-Ar recalculation K-Ar recalculation	muscovite biotite	99.1 +/- 3.2 101.5[c] 92.2 +/- 3.0 94.5[c]	Yates & Engels, 1968[1]

Table 1. Isotopic ages of rocks in the Colville 1:100,000-scale quadrangle (continued)

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
17	26	undivided two-mica granitic rocks	Kiat	48°45'N 117°28'W	K-Ar	biotite	78.5 +/- 2.4	Miller & Engels, 1975[2]
					recalculation		80.5 +/- 2.4	Burmester & Miller, 1983
					K-Ar	muscovite	85.9 +/- 2.6	Miller & Engels, 1975[2]
					recalculation		88.1 +/- 2.6	Burmester & Miller, 1983
18	28	undivided two-mica granitic rocks	Kiat	48°44'N 117°33'W	K-Ar	biotite	92.2 +/- 3.0	Miller & Engels, 1975[2]
					recalculation		94.5 +/- 3.0[c]	
19	30	undivided two-mica granitic rocks	Kiat	48°39'N 117°30'W	K-Ar	biotite	79 +/- 3	Miller & Engels, 1975[2]
					recalculation		81 +/- 3[c]	
					K-Ar	muscovite	84 +/- 4	
					recalculation		86 +/- 4[c]	
20	33	undivided two-mica granitic rocks	Kiat	48°36'N 117°22'W	K-Ar	biotite	51.2 +/- 1.5[b]	Miller & Engels, 1975[2]
					recalculation		52.5 +/- 1.5[c]	
21	34	undivided two-mica granitic rocks	Kiat	48°35'N 117°21'W	K-Ar	biotite	49.3 +/- 1.5[b]	Miller & Engels, 1975[2]
					recalculation		50.6 +/- 1.5[c]	
						muscovite	55.9 +/- 1.7[b]	
					recalculation		57.3 +/- 1.7[c]	
22	92	undivided two-mica granitic rocks	Kiat	48°31'N 117°40'W	K-Ar	biotite	74 +/- 2	Miller & Engels, 1975[2]
					recalculation		75 +/- 2[c]	
						muscovite	89 +/- 6	
					recalculation		91 +/- 6[c]	

Table 1. Isotopic ages of rocks in the Colville 1:100,000-scale quadrangle (continued)

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
23	31	biotite granite near Narcisse Creek	Kia_n	48°35'N 117°35'W	K-Ar	biotite	98.0 +/- 2.9	Miller & Engels, 1975[2]
					recalculation		100.4 +/- 2.9[c]	
			On the upper plate of the Newport fault					
24	23	Sand Creek monzogranite	Kig_s	48°48'N 117°21'W	K-Ar	biotite	96.3 +/- 2.9	Miller & Engels, 1975[2]
					recalculation		98.7 +/- 3.0	Burmester & Miller, 1983[3]
25	24	granodiorite of Molybdenite Mountain	$Kiat_m$	48°43'N 117°20'W	K-Ar	biotite	101 +/- 3.0	Miller & Yates, 1975[2]
					recalculation		103 +/- 3.0[c]	
						muscovite	101 +/- 3.0	
					recalculation		103 +/- 3.0[c]	
26	25	granodiorite of Yocum Lake	$Kigd_y$	48°40'N 117°17'W	K-Ar	biotite	97.9 +/- 2.9	Miller & Engels, 1975[2]
					recalculation		100.5 +/- 2.9	
						hornblende	97.4 +/- 2.0	
					recalculation		99.8[c]	
27	32	granodiorite of Yocum Lake (west of Pend Oreille River)	$Kigd_y$	48°37'N 117°22'W	K-Ar	biotite	96.7 +/- 2.9	Miller & Engels, 1975[2]
					recalculation		99.1 +/- 2.9[c]	
28	35	monzogranite of Hungry Mountain	$Kiat_{hm}$	48°36'N 117°04'W	K-Ar	biotite	90.0 +/- 2.7	Miller & Engels, 1975[2]
					recalculation		92.3 +/- 2.7[c]	
						muscovite	94.3 +/- 2.8	
					recalculation		96.7 +/- 2.8[c]	

Table 1. Isotopic ages of rocks in the Colville 1:100,000-scale quadrangle (continued)

Sample locality	Original sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
29	2D	Orwig Hump pluton of granodiorite of Hall Mountain	$Kiat_{ho}$	48°43'N 117°04'W	K-Ar recalculation	biotite	84.6 +/- 2.5 86.7 +/- 2.5[c]	Miller & Engels, 1975[2]
30	21	monzogranite of Granite Pass	$Kiat_{gp}$	48°46'N 117°04'W	K-Ar	muscovite	95.4 +/- 2.9	Miller & Engels 1975[2]
					recalculation		97.8 +/- 2.9	Miller, 1983
31	22	Hall Mountain pluton of the granodiorite of Hall Mountain	$Kiat_{h}$	48°48'N 117°13'W	K-Ar	biotite	96.6 +/- 2.9	Miller & Engels, 1972[2]
					recalculation		99.0 +/- 3.0	Miller, 1983

a Age thought to be too young, possibly because of argon loss due to circulating ground water (Yates & Engels, 1968).

b K-Ar dates on the lower plate of Newport fault appear to be increasingly younger proportionately closer to the fault zone.

c Recalculated using Dalrymple (1979).

Decay constants from

1 Yates and Engels (1968): $\lambda_\varepsilon = 0.585 \times 10^{-10}\ yr^{-1}$; $\lambda_\beta = 4.72 \times 10^{-10}\ yr^{-1}$; K^{40}/K total $= 1.19 \times 10^{-2}$ atom present

2 Miller and Engels (1975): $\lambda_\varepsilon = 4.72 \times 10^{-10}\ yr^{-1}$; $\lambda_\beta = 0.584 \times 10^{-10}\ yr^{-1}$; K^{40}/K total $= 1.19 \times 10^{-4}$ mol/mol

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
--	O'Brien Creek Formation	Gold Creek	NW/4NW/4SW/4 sec. 1 T.35N., R.38E.	J. Gray	needles, leaves	Eocene	Bradshaw, 1964
89BZ199R (USGS colln. Mes. 33334)	Upper Triassic carbonate rocks	Flat Creek	lat. 48°52.8' long. 117°59.9'	A. G. Harris	conodonts	Triassic, Karnian-early Norian	A. G. Harris, U.S.G.S. written commun., 1989
89BZ273	Upper Triassic carbonate rocks	Cougar Mountain	lat. 48°55.2' long. 117°55.3'	A. G. Harris	conodonts	Permian-Triassic	A. G. Harris, U.S.G.S. written commun., 1989
89BZ274B (USGS colln. Mes. 33335)	Upper Triassic carbonate rocks	Cougar Mountain	lat. 48°54.5' long. 117°54.8'	A. G. Harris	conodonts	early Late Triassic, Karnian-early Norian	A. G. Harris, U.S.G.S. written commun., 1989
USGS colln. 30215-PC	Rossland Group, congolmerate	Boundary Creek	NE/4SW/4NE/4 sec. 11, T.40N., R.39E.	A. G. Harris	conodonts, crinoid	late Early Permian Permian	A. G. Harris, U.S.G.S. written commun., 1988
--	Rossland Group, conglomerate	Little Sheep Creek	NW/4NE/4 sec. 11, T.40N., R.39E.	--	crinoid	--	Yates, 1971
S3	Permian carbonate rock near Kettle Falls	Pingston Creek	NE/4 sec. 34 T.37N., R.38E.	--	fusulinid, ostracod	Pennsylvanian?	West, 1976
--	Carboniferous - Devonian metasedimentary rocks	Flagstaff Mountain barite deposit	SW/4NW/4 sec. 4, T.39N., R.39E.	G. D. Webster	conodonts	late Middle Devonian	Adekoya, 1983
289	Carboniferous - Devonian metasedimentary and metavolcanic rocks	Sand Point	sec. 30, T.40N., R.40E.	G. D. Webster	conodonts	Late Devonian, Famennian(?)	Beka, 1980

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
174	Upper Triassic carbonate rocks	Ansaldo Lake	sec. 1, T.39N., R.38E.	G. D. Webster	conodonts	Devonian, late Famennian	Beka, 1980
49	Carboniferous - Devonian carbonate rocks	Flagstaff Mountain	sec. 4, T.39N., R.39E.	G. D. Webster	conodonts	early Middle Devonian	Beka, 1980
JD8	Carboniferous - Devonian metasedimentary rocks	Alice Mountain	NW/4SW/4 sec. 4, T.38N., R.39E.	G. D. Webster	conodonts	Devonian? Early Mississippian?	P. R. Jackson written commun., 1990
389	Carboniferous - Ordovician carbonate rocks	Uribe mine	NE/4 sec. 5 T.37N., R.39E.	G. D. Webster; C. A. Sandberg	conodonts	Devonian, early Famennian, Upper crepida Zone	Laskowski, 1982; Sandberg and others, 1988
--	Carboniferous - Devonian metasedimentary rocks	Black Canyon	sec. 7, T.39N., R.41E.	J. T. Dutro, Jr.	coral	Silurian - Devonian	Yates, 1976
N39-41-07-4a	Carboniferous - Devonian metasedimentary rocks	Black Canyon	sec. 7, T.39N., R.41E.	A. G. Harris	conodonts	Post-Silurian (probably post-Early Devonian)	A. G. Harris, U.S.G.S. written commun., 1988
--	Carboniferous - Devonian metasedimentary rocks	Columbia River	sec. 4, T.40N., R.41E. elev. 1,480 ft. (451 m)	J. T. Dutro, Jr.	fossil hash	Paleozoic	Yates, 1976
--	Carboniferous - Devonian metasedimentary rocks	Stone Mountain	sec. 15, T.40N., R.41E.	--	crinoid	--	Yates, 1976
C7266	Limestone on Limestone Hill	Limestone Hill	SE/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Frasnian	Greenman and others, 1977

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
C7267	Limestone on Limestone Hill	Limestone Hill	Center sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, early Frasnian	Greenman and others, 1977
C821	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Givetian - probably Frasnian	Greenman and others, 1977
C894	Silurian metasedimentary rocks	Whiskey Creek	NW/4 sec. 34, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian, Ludlovian, *siluricus* Zone	Greenman and others, 1977
C911	Silurian metasedimentary rocks	Whiskey Creek	NW/4SW/4 sec. 34, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian to early Devonian	Greenman and others, 1977
C912	Silurian metasedimentary rocks	Whiskey Creek	NW/4SW/4 sec. 34, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian Ludlovian	Greenman and others, 1977
C981	Silurian metasedimentary rocks	Horsefly Hill	SE/4NE/4 sec. 28, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian	Greenman and others, 1977
C8224	Limestone and limestone conglomerate	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton			Greenman and others, 1977
	from matrix of C8224				conodonts	Early Devonian	
	from clast of C8224				conodonts	Early to Middle Devonian	
C8314	Limestone and limestone conglomerate	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton			Greenman and others, 1977
	from matrix of C8314				conodonts	Devonian, Givetian	
	from clast of C8314				conodonts	Devonian, Emsian to Eifelian	

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
B751	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	A. J. Boucot	brachiopod	Devonian, post-Frasnian	Greenman and others, 1977
S9131	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	W. A. Oliver	coral	Middle to Late Devonian	Greenman and others, 1977
S9134	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 28, T.40N., R.34E.	W. A. Oliver, Jr.	coral	Silurian to Devonian	Greenman and others, 1977
S9135	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 28, T.40N., R.34E.	W. A. Oliver, Jr.	coral	Silurian to Devonian	Greenman and others, 1977
C9117	Limestone on Limestone Hill	Limestone Hill	NE/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Givetian	Greenman and others, 1977
C7192	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Givetian to Frasnian	Greenman and others, 1977
C7201	Limestone on Limestone Hill	Limestone Hill	NW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Givetian to Frasnian	Greenman and others, 1977
C7202	Limestone on Limestone Hill	Limestone Hill	SW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Devonian, Frasnian, Lower Gigas Zone	Greenman and others, 1977
C7231	Limestone on Limestone Hill	Limestone Hill	SW/4 sec. 16, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Ordovician - Devonian	Greenman and others, 1977
G981	Silurian metasedimentary rocks	Horsefly Hill	SE/4NE/4 sec. 28, T.40N., R.43E.	W. B. N. Berry	graptolite	Silurian, late Llandoverian	Greenman and others, 1977
G961	Silurian metasedimentary rocks	Horsefly Hill	SE/4 sec. 28, T.40N., R.43E.	W. B. N. Berry	graptolite	Silurian, late Llandoverian	Greenman and others, 1977
G941	Silurian metasedimentary rocks	Horsefly Hill	NW/4SE/4 sec. 28, T.40N., R.43E.	W. B. N. Berry	graptolite	Silurian, Wenlockian	Greenman and others, 1977

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
G9101	Silurian metasedimentary rocks	Horsefly Hill	NE/4NW/4 sec. 28, T.40N., R.43E.	W. B. N. Berry	graptolite	Silurian, Llandoverian Wenlockian	Greenman and others, 1977
G851	Quartz granule conglomerate on Basalt Hill	Basalt Hill	S1/2NE/4 sec. 33, T.40N., R.43E.	W. B. N. Berry	graptolite	Silurian, Early Devonian	Greenman and others, 1977
65WCN111	Silurian metasedimentary rocks	Everett Creek	NW/4 sec. 27, T.40N., R.34E.	C. Carter	graptolite	Silurian	Carter, 1989b
C-836	Silurian metasedimentary rocks	Horsefly Hill	SE/4NW/4 sec. 28, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian Early Devonian	Greenman and others, 1977
C-871	Silurian metasedimentary rocks	Basalt Hill	SW/4 sec. 33, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian, Ludlovian, latialata Zone	Greenman and others, 1977
C-872	Silurian metasedimentary rocks	Whiskey Creek	SW/4 sec. 33, T.40N., R.43E.	B. D. E. Chatterton	conodonts	Silurian, Ludlovian - late Ludlovian	Greenman and others, 1977
C-882	Silurian metasedimentary rocks	--	--	B. D. E. Chatterton	conodonts	Silurian, Ludlovian, siluricus Zone	Greenman and others, 1977
G-819	Ledbetter Slate	Beaver Mountain	SE/4NW/4 sec. 4, T.39N.,R.43E.	W. B. N. Berry	graptolite	Middle Ordovician	Greenman and others, 1977
G-9211	Ledbetter Slate	Beaver	NW/4 sec. 3, T.39N., R.43E.	W. B. N. Berry	graptolite	Late Middle Ordovician	Greenman and others, 1977

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
G-972	Ledbetter Slate	Horsefly Hill	SE/4 sec. 28, T.40N., R.43E.	W. B. N. Berry	graptolite	latest Ordovician	Greenman and others, 1977
71-105	Ledbetter Slate	Clugston Creek	East of center sec. 3, T.37N., R.39E.	W. B. N. Berry	graptolite	Middle Ordovician	Schuster, 1976
73-26	Ledbetter Slate	Neglected mine	NW/4 sec. 11, T.37N., R.39E.	W. B. N. Berry	graptolite	Ordovician	Schuster, 1976
75-9	Ledbetter Slate	Clugston Creek	N1/2NW/4 sec. 14, T.37N., R.39E.	W. B. N. Berry	graptolite	Middle Ordovician	Schuster, 1976
75-5	Ledbetter Slate	Southeast flank of Baldy	E1/16 cor.,NW/4 sec 14, T.37N., R.39E.	W. B. N. Berry	graptolite	Early to Middle Ordovician	Schuster, 1976
75-50	Ledbetter Slate	Clugston Creek	N1/2NW/4 sec. 23, T.37N., R.39E.	W. B. N. Berry	graptolite	Early to Middle Ordovician	Schuster, 1976
72-430	Ledbetter Slate	Tenderfoot mine	W1/16 cor.,SE/4 sec. 23, T.37N., R.39E.	M. E. Taylor	trilobite, sponge, crustacean	Early Ordovician	Schuster, 1976
B-90	Ledbetter Slate	Mouth of Slate Creek	sec. 35, T.40N., R.43E.	Josiah Bridge, C. Carter	graptolite	Middle Ordovician	Park and Cannon, 1943; Carter, 1989b
B-456	Ledbetter Slate	Boundary Dam 7.5' quad	SW/4 sec. 30, T.40N., R.44E.	Josiah Bridge C. Carter	graptolite	Middle Ordovician, C. bicornis Subzone	Park and Cannon, 1943; Carter, 1989b;
10690-CO	Metaline Formation	Clugston Creek	N.48°44'10" W.117°52'33"	J. E. Repetski	conodonts	late Early Ordovician	Schuster and others, 1989
10691-CO	Metaline Formation	Clugston Creek	N.48°44'10" W.117°52'35"	J. E. Repetski	conodonts	early Middle Ordovician	Schuster and others, 1989

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
D511-CO	Metaline Formation (upper part)	Leadpoint 7.5' quadrangle	sec. 3, T.39N., R.41E. elev. 3,880 ft. (1,183 m)	C. Carter	graptolite	Middle Ordovician, C. bicornis Subzone	Carter, 1989b
GSWCN-92	Ledbetter Slate	Black Canyon	NE/4 sec. 13, T.39N., R.40E.	C. Carter	graptolite	Middle Ordovician, C. bicornis Subzone	Carter, 1989b
--	Ledbetter Slate	Swede Hill	NW/4 sec. 22, T.37N., R.39E.	G. D. Webster	conodonts	Middle Ordovician	Hogge, 1982
B-87	Ledbetter Slate	Pend Oreille mine	sec. 16 T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, B? decoratus & N. gracilis Subzone	Carter, 1989b
B-459	Ledbetter Slate	Boundary Dam 7.5'	sec. 15, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, N. gracilis Subzone	Carter, 1989b; Park and Cannon, 1943
65WCN-91	Ledbetter Slate	Black Canyon	NW/4 sec. 18, T.39W., R.41E.	C. Carter	graptolite	Middle Ordovician, N. gracilis Subzone	Carter, 1989b
B-462	Ledbetter Slate	Road SW of Ledbetter Lake	NW/4 sec. 10, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Park and Cannon, 1943; Carter, 1989b
66Y-200	Sheared contact between Metaline Formation and Ledbetter Slate	Leadville	sec. 3, T.37N., R.39E.	C. Carter	graptolite	Middle Ordovician, N. gracilis Subzone	Carter, 1989b
65WCN-102	Ledbetter Slate	Road west of Ledbetter Lake	NW/4 sec. 3, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Carter, 1989b
B-86	Ledbetter Slate	Road SW of Ledbetter Lake	sec. 3 T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Park and Cannon, 1943; Carter, 1989b
B-88	Ledbetter Slate	Metaline 7.5' quad.	sec. 32 T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Park and Cannon, 1943; Carter, 1989b

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
B-89	Ledbetter Slate	Boundary Dam 7.5' quad.	sec. 2, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Park and Cannon, 1943; Carter, 1989b
B-462	Ledbetter Slate	Road SW of Ledbetter Lake	NW/4 sec. 10, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician, C. spiniferus Zone	Park and Cannon, 1943; Carter, 1989b
D-1502-CO	Ledbetter Slate	Road SW of Ledbetter Lake	NW/4 sec. 3, T.39N., R.43E.	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
B-92	Ledbetter Slate	Lead Hill mine road	NE/4 sec. 22 T.40N., R.44E.	Josiah Bridge	graptolite	Middle Ordovician	Park and Cannon, 1943
B-91	Ledbetter Slate	Gypsy Peak 7.5' quad.	sec. 12, T.40N., R.44E.	Josiah Bridge	graptolite	Middle Ordovician	Park and Cannon, 1943
B-94	Ledbetter Slate	Metaline Falls	--	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
D510-CO	Metaline Formation	Leadpoint 7.5' quad.	sec. 3, T.39N., R.41E. elev. 3,440 ft. (1,048 m)	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
D-914	Metaline Formation	Pend Oreille mine	1,700 foot level, 1724 slope	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
2181	Ledbetter Slate	Anderson prospect	SW/4NW/4NE/4 sec. 3, T.39N., R.41E. elev. 3,440 ft. (1,048 m)	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
2182	Ledbetter Slate	Head of Sherlock Creek	SW/4NE/4 sec. 17, T.39N., R.41E.	C. Carter	graptolite	Middle Ordovician	Carter, 1989b
2180-CO	Ledbetter Slate	Leadpoint 7.5' quad.	NE/4NW/4 sec. 20 T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
D508-CO	Ledbetter Slate	Iroquois mine	NE/4 sec. 30, T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b
2178-CO	Ledbetter Slate	Iroquois mine road	NE/4NE/4NE/4 sec. 30, T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b
2179-CO	Ledbetter Slate	Terry trail	NE/4NW/4 sec. 20, T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b
2180-CO	Ledbetter Slate	Terry trail	NE/4NW/4 sec. 20 T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b
1071	Ledbetter Slate	Iroquois mine	sec. 30, T.40N., R.42E.	C. Carter	graptolite	Early Ordovician	Carter, 1989b
B4589,b	Ledbetter Slate	Boundary Dam 7.5' quad.	sec. 16, T.39N., R.43E. elev. 3,440 ft. (1,049 m)	Josiah Bridge	graptolites	Early and Middle Ordovician, Oncograptus Zone	Park and Cannon, 1943; Carter, 1989b
D354-CO	Ledbetter Slate	Scandia mine	NE/4 sec. 23, T.39N., R.40E.	C. Carter	graptolites	Early Ordovician, Oncograptus Zone	Carter, 1989b
913-CO	Metaline Formation (40' below contact with Ledbetter)	Pend Oreille mine (1700' level)	sec. 15, T.39N., R.43E.	C. Carter	graptolites	Early to Middle Ordovician, P. tentaculatus Zone	Carter, 1989b
--	Metaline Formation, dolomite	Gladstone Mountain	--	Josiah Bridge	brachiopod	Early Middle Cambrian	Yates, 1976
F-9	Metaline Formation, dolomite	Republican Creek	sec. 19, T.39N.,R.42N. elev. 3,320 ft. (1,012 m)	A. R. Palmer	brachiopod	Middle Cambrian	Yates, 1976

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
F-13	Metaline Formation, dolomite	Leadpoint	sec. 7, T.39N., R.42E. elev. 3,680 ft. (1,211 m)	A. R. Palmer	brachiopod	Middle Ordovician or older	Yates, 1976
F-14	Metaline Formation, dolomite	Leadpoint	sec. 7, T.39N., R.42E. elev. 3,760 ft. (1,146 m)	Josiah Bridge	brachiopod	early Middle Cambrian	Park and Cannon, 1943
F-4	Metaline Formation, limestone	Leadpoint quadrangle	sec. 14, T.39N., R.41E. elev. 2,480 ft. (756 m)	A. R. Palmer	brachiopod	Middle Ordovician or older	Yates, 1976
F-7	Metaline Formation, limestone	Sherlock Creek	sec. 14, T.39N., R.41E. elev. 2,720 ft. (829 m)	A. R. Palmer	brachiopod trilobite	Late Cambrian Early Ordovician	Yates, 1976
F-6	Metaline Formation, bedded unit	Sherlock Creek	sec. 14, T.39N., R.41E. elev. 2,320 ft. (707 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976
55-R-7	Metaline Formation, bedded unit	Leadpoint	sec. 6, T.39N., R.42E. elev. 3,440 ft. (1,049 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976
55-R-8	Metaline Formation, bedded unit	Leadpoint	sec. 6, T.39N., R.42E. elev. 3,300 ft. (1,006 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976
55-R-13	Metaline Formation, bedded unit	Deep Lake	sec. 31, T.40N., R.42E. elev. 3,660 ft. (1,116 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976
55-R-18	Metaline Formation, bedded unit	Deep Lake	sec. 31, T.40N., R.42E. elev. 3,700 ft. (1,138 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976
61-1 (3798-CO)	Metaline Formation, bedded unit	Deep Lake	sec. 31, T.40N., R.42E. elev. 3,700 ft. (1,138 m)	A. R. Palmer	brachiopod	middle Middle Cambrian	Yates, 1976

Table 2. Selected fossil localities on the Colville 1:100,000-scale quadrangle (continued)

Collection Number	Rock Unit	Area	Location	Identified by	Fossil	Age and Zone	Reference
--	Metaline Formation	Quarry Hill, main Lehigh quarry		A. V. Okulitch	trilobite	Middle Cambrian	Dings and Whitebread, 1965
--	Metaline Formation	Upper Lehigh quarry		Josiah Bridge	trilobite	Middle Cambrian	Park and Cannon, 1943
--	Metaline Formation	Threemile Creek	SW/4 sec. 12, T.39N., R.43N.	Josiah Bridge	trilobite	Middle Cambrian	Park and Cannon, 1943
--	Metaline Formation	Pend Oreille mine	Between 500- and 700-foot levels	Josiah Bridge	trilobite	Middle Cambrian	Park and Cannon, 1943
BYU	Maitlen Phyllite, limestone	Douglas Lake	SW/4NE/4 sec. 22, T.36N., R.39E.	G. L. Hampton	archaeocyathids, echinoid plates, bryozoan	Early Cambrian	Hampton, 1978
BYU	Maitlen Phyllite, limestone	Douglas Lake	N1/2SE/4 sec. 22, T.36N., R.39E.	G. L. Hampton	archaeocyathids	Early Cambrian	Hampton, 1978
BYU	Maitlen Phyllite, limestone	Douglas Lake	SE/4NE/4 sec. 22, T.36N., R.39E.	G. L. Hampton	archaeocyathids	Early Cambrian	Hampton, 1978
BYU-2319	Maitlen Phyllite, limestone	Douglas Lake	NW/4NW/4 sec. 14, T.36N., R.39E.	A. R. Palmer	trilobite, archaeocyathids, brachiopod	Early Cambrian	Hampton, 1978
--	Gypsy Quartzite	Gypsy Peak	NW/4 sec. 18, T.40N., R.45E.	Josiah Bridge	trilobite	Cambrian	Park and Cannon, 1943