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

Compiled by

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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES

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

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

WASHINGTON STATE DEPARTMENT OF
Natural Resources
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GEOLOGIC MAP OF THE CHEWELAH 1:100,000 QUADRANGLE, WASHINGTON AND IDAHO

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INTRODUCTION

The Chewelah quadrangle is one of sixteen 1:100,000-scale quadrangles covering the northeast quadrant of Washington (Fig. 1). Geologic maps of these quadrangles were compiled by Washington Division of Geology and Earth Resources (DGER) geologists and are the principal data sources for a new 1:250,000-scale geologic map of northeastern Washington. Except for the Chelan and Wenatchee quadrangles the 1:100,000-scale quadrangles are available as DGER open-file reports (listed below). The Chelan and Wenatchee quadrangles (Tabor and others, 1982, 1987) have been published by the U.S. Geological Survey (USGS).

The Chewelah 1:100,000-scale quadrangle open-file report consists of a geologic map compilation (Plate I) and a description of the map units. Tables present new whole-rock geochemical data for intrusive and extrusive rocks, results of conodont dating of carbonate rocks, and isotopic ages for some sedimentary deposits, volcanic, metasedimentary, igneous, and metamorphic rocks.

Sources of geologic mapping used in the compilation of the Chewelah 1:100,000-scale quadrangle are shown in Figure 2. Areas where mapping was inadequate or where differences among source maps had to be resolved were field checked or mapped by DGER geologists (Fig. 2). New geologic mapping was also acquired through the DGER graduate student mapping program and through contracts for geologic mapping.

Rock units of greenschist facies are included under the heading Metasedimentary and Metavolcanic Rocks, whereas those below greenschist-facies grade are included under Sedimentary and Volcanic Rocks and Deposits or Intrusive Rocks. Units included under the heading Metamorphic Rocks are limited to those of amphibolite facies or higher. Intrusive rocks displaying strongly developed secondary foliation are shown on Plate I as orthogneiss regardless of their metamorphic grade. If modal analyses are given in source data, rock names were assigned to intrusive rocks using the system recommended by the International Union of Geological Sciences (IUGS) (Streckeisen, 1973). (Rock names of formally named plutons remain unchanged even though some do not represent the rock type(s) according to the IUGS system.) On the basis of new whole-rock geochemical data, volcanic rock names are assigned using the total alkali-silica (TAS) diagram (Zannettin, 1984).

Age assignments of geologic units were made following the flow chart in Figure 3. The Phanerozoic time scale devised by the American Association of Petroleum Geologists for the Correlation of Stratigraphic Units of North America (COSUNA) project (Salvador, 1985), with slight modification of the Eocene-Oligocene and Pliocene-Pleistocene boundaries (Aguirre and Pasini, 1985; Armentrout and others, 1983; Montanari and others, 1985; Prothero and Armentrout, 1985), is used for this report. The Precambrian time scale adopted by the North American Commission on Stratigraphic Nomenclature (Harrison and Peterman, 1982) is used for the area's older rocks.

Some K-Ar ages, (particularly those more than 12 years old) are recalculated with currently accepted constants. (See Steiger and Jaeger, 1977). Several new K-Ar ages are presented in this report (Table 1). (All tables follow the listing of cited references.)

Geologic map symbols designate age and lithology. Upper-case letters indicate unit age, and lower-case letters indicate lithology; subscripts indicate the formal or informal name of a unit. Thus, the Flowery Trail Granodiorite, a Jurassic-Triassic pluton that has an intermediate range in composition, is portrayed on the map as $J\bar{R}\,ii_f$.

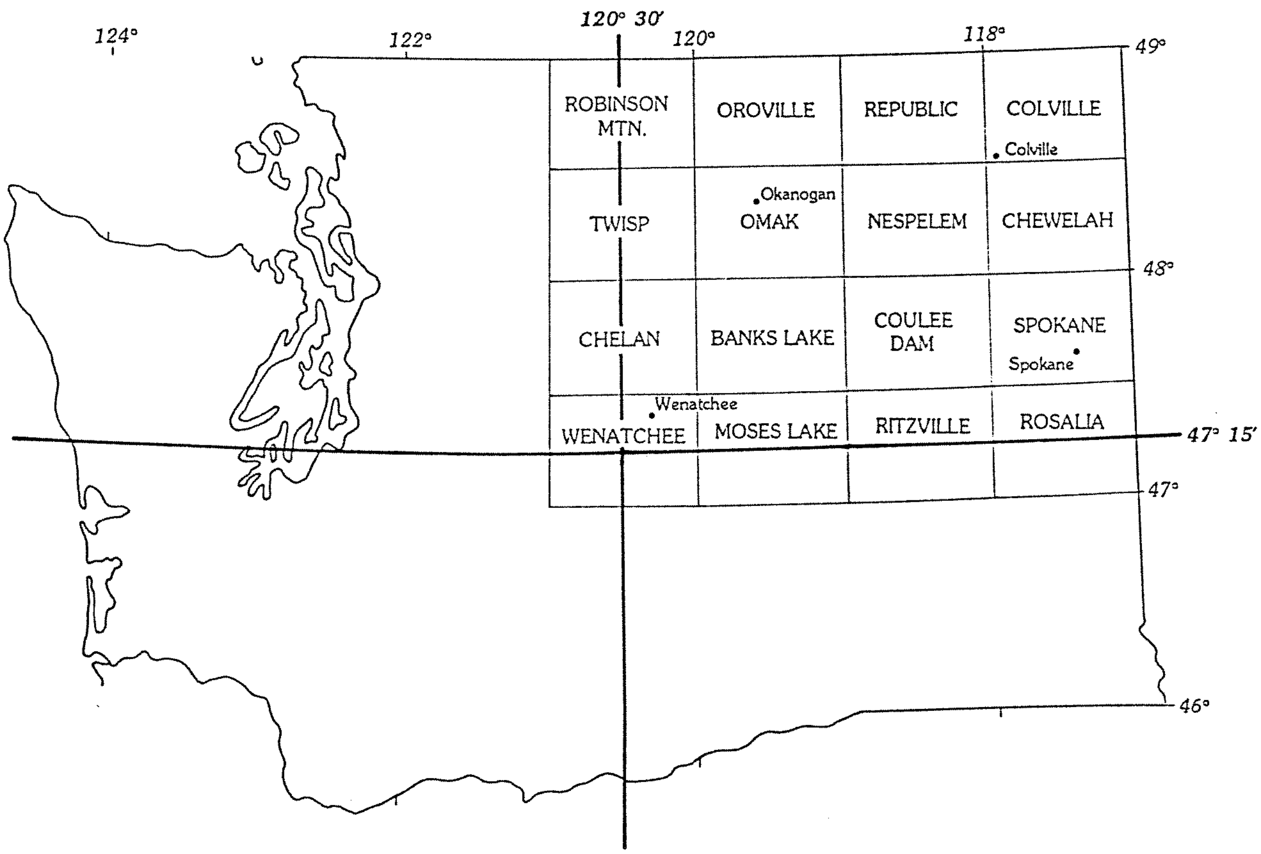


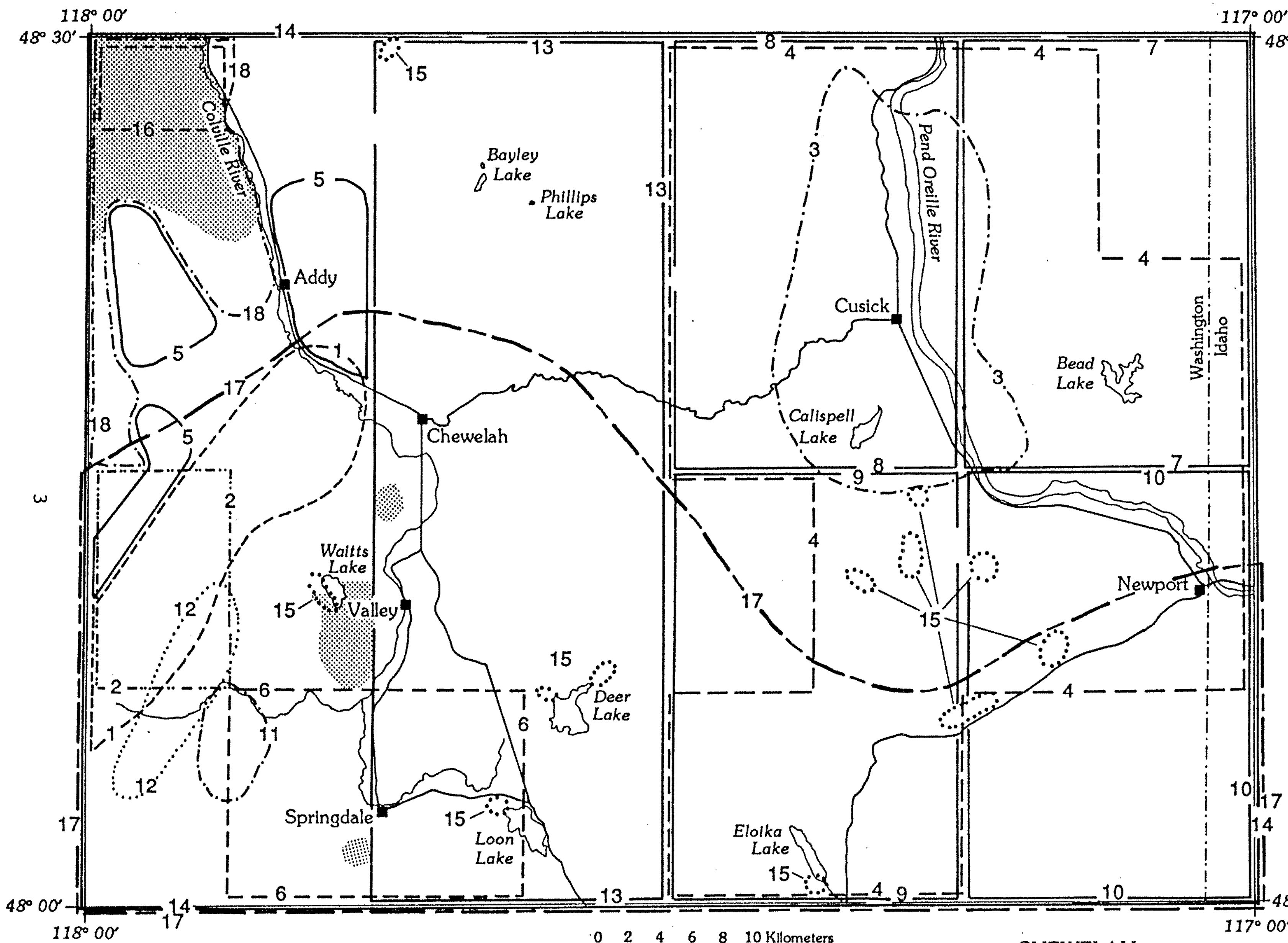
Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Sources of Map Data

Explanation for Figure 2 (facing page)

1. Campbell and Loofbourow, 1962, plate 1, scale 1:36,000.
2. Evans, 1987, plate 1, scale 1:24,000.
3. Gager, 1982, plate C, scale 1:36,000.
4. Kiver, E. P.; Stradling, D. F., Eastern Washington University, written communication, 1987, 12 maps, scale 1:24,000.
5. Lindsey, 1988, plate 1, scale 1:24,000; plate 2, scale 1:24,000; plate 4, scale 1:24,000.
6. McLucas, 1980, plate 1, scale 1:24,000;plate 2, scale 1:24,000.
7. Miller, 1974a, 1 plate, scale 1:62,500.
8. -----, 1974b, 1 plate, scale 1:62,500.
9. -----, 1974c, 1 plate, scale 1:62,500.
10. -----, 1974d, 1 plate, scale 1:62,500.
11. Miller, F. K., USGS, written communication, 1988, 2 maps, scale 1:24,000.
12. Miller, F. K., USGS, written communication, 1988. 2 map, scale 1:24,000.
13. Miller and Clark, 1975, plate 1, scale 1:62,500; plate 2, scale 1:62,500.
14. Miller and Yates, 1976, sheet 1, scale 1:125,000.
15. Rigg, 1958, 13 figures with scales ranging from 1:21,600 to 1:81,000.
16. Snook, 1981, plate 1, scale 1:6,000.
17. Swanson and others, 1979a, plate 2, scale 1:250,000.
18. Yates, R. G., USGS, retired, written communication, 1986, 4 maps, scale 1:24,000.

DGER unpublished mapping (this report) shown by shaded areas.



CHEWELAH
1:100,000 quadrangle

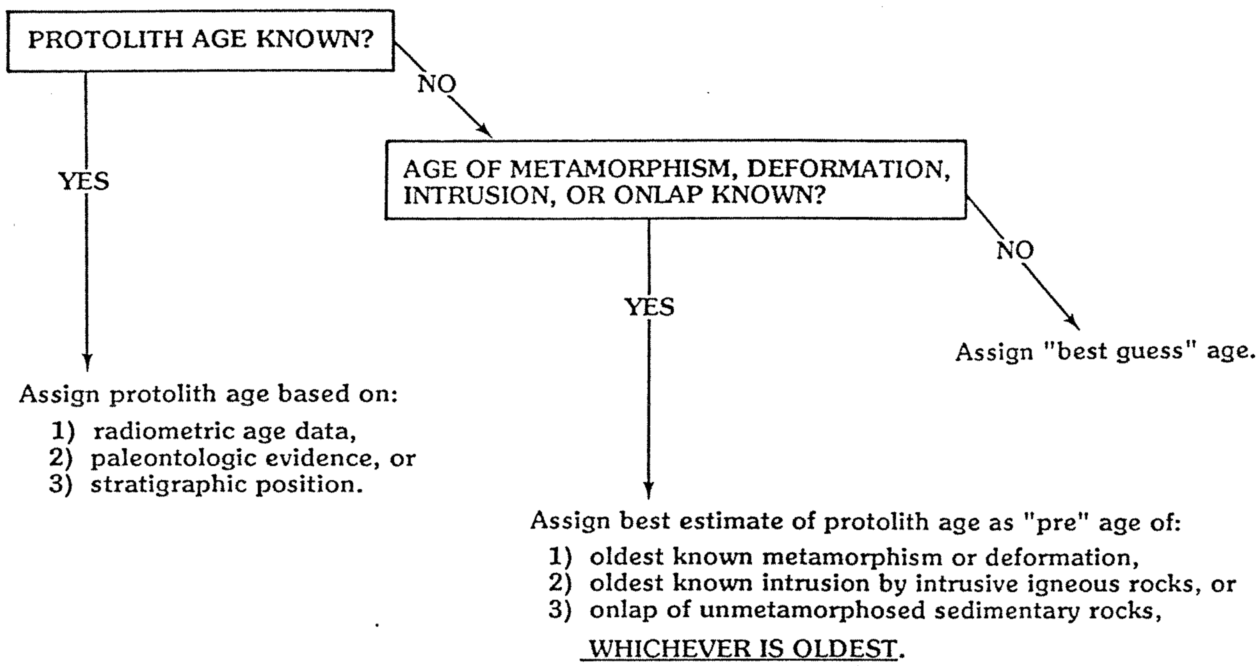


Figure 3. Flow chart for age assignment of geologic units, Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description includes information on how the age of the unit was determined.

DGER Northeast Quadrant Open-File Reports

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

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

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

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

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

The author thanks the many people who contributed to this report during its preparation: F. K. Miller (USGS) provided unpublished geologic mapping and reviewed the manuscript and geologic map. His discussions of many aspects of the geology are especially appreciated. A. G. Harris (USGS) identified the conodonts and reviewed the manuscript. K. A. Lindsey (Westinghouse Geoscience Group) readily shared his detailed knowledge of the Addy Quartzite and reviewed the manuscript. R. G. Yates (USGS, retired) shared field maps for the Arden area. J. W. Whipple (USGS) and J. G. Evans (USGS) provided insight into several features of the Precambrian rocks. J. T. Dutro, Jr. (USGS) visited and examined many of the Paleozoic carbonate exposures in the map area with the author. B. B. Bunning (formerly DGER) began the conodont sampling in the map area. T. J. Walsh (DGER) mapped the Eocene volcanic rocks in the Waitts Lake - Long Prairie area; he also provided petrographic expertise. E. P. Kiver, Eastern Washington University (EWU), provided insight into the Quaternary geology of the Pend Oreille River valley. K. L. Stoffel (DGER) and N. L. Joseph (DGER) helped in many ways during preparation of the report. N. A. Eberle and J. R. Snider (both DGER) assisted with the illustrations and final format.

DESCRIPTION OF MAP UNITS

Sedimentary and Volcanic Rocks and Deposits

Quaternary Unconsolidated Sedimentary Deposits

Nonglacial Sedimentary Deposits

Qa

Alluvium (Holocene)--Stratified to unstratified and well-sorted to poorly sorted boulders, cobbles, gravel, sand, silt, and clay in floodplains of modern streams and rivers and in abandoned outwash channels and closed depressions that accommodate ephemeral streams and ponds. In some places the unit includes alluvial fan deposits, postglacial lacustrine and eolian silts, as well as minor organic deposits. Discontinuous layers and lenses of volcanic ash are exposed in some places.

Qp

Peat deposits (Holocene)--Dominantly fibrous and sedimentary peat, muck, and organic-rich alluvium, as well as subordinate woody peat and moss peat. Some deposits include layers or lenses of marl, diatomite, pumicite, and blue or green clay. Drill data indicate that the deposits are generally floored by clay and/or sand. Peat deposits and organic-rich alluvium are typically found adjacent to modern lakes and in meadows, closed depressions, valleys of sluggish streams, and abandoned outwash channels. The distribution of most peat deposits shown on Plate I is from Rigg (1958).

Qla

Lacustrine deposits (Holocene)--Mostly clay, silt, and sand and minor pebbly sand deposited in a lake that occupied the Pend Oreille River valley and the Calispell Lake basin at some time during the Holocene. Preserved shoreline features indicate the lake surface stood at an elevation of about 630 m (E. P. Kiver, EWU, oral commun., 1988). Charcoal from the unit yielded a ^{14}C age estimate of 5,870 yr B.P. (Table 1).

Nonglacial and Glacial Sedimentary Deposits

Qs

Unconsolidated sedimentary deposits, undivided (Holocene to Pleistocene)--Gravel, sand, silt, clay, and less common boulder-bearing sediments of glacial, periglacial, and modern fluvial origins. The unit includes some outburst flood gravels, talus, colluvium, and peat or organic-rich alluvium.

Qls

Landslide deposits (Holocene to Pleistocene)--Unstratified, unsorted deposits of varied amounts of clay, silt, sand, gravel and/or rock debris deposited by rotational and translational movements. The unit includes slumps, earthflows, rockslides, colluvium, and talus. Talus and colluvium are common at the bases of cliffs and steep slopes of resistant rock.

Ql

Loess (Holocene to Pleistocene)--Eolian silt and fine sand. The only occurrences shown on Plate I are northeast of Eloika Lake.

Glacial Sedimentary Deposits

Most glacial deposits are restricted to elevations below about 1,500 m even though the effects of alpine glaciation are apparent on some of the higher peaks (E. P. Kiver and D. F. Stradling, EWU, written commun., 1987; Miller and Clark, 1975). Glacial deposits and glacial outburst flood deposits are typically reworked and eroded, but geomorphic features such as moraines, outwash plains, kettles, kame terraces, mega-ripples, and mega-gravel bars are still preserved in many places.

Qfg, Qfs

Outburst flood deposits (Pleistocene)--Sediments deposited by water from the late Wisconsin outburst floods of glacial Lake Missoula.

Qfg

Chiefly poorly sorted, coarse gravel and sand. Subrounded to angular clasts consist of diverse lithologies. In many places the deposits display foreset bedding and contain tephra layers.

Qfs

Sand and silt--Graded sand and silt and some gravel deposited by ponded water (low-energy slackwater).

Qgl

Glaciolacustrine deposits (Pleistocene)--Dense, well-bedded, laminated (varved) clay and silt that are typically found in terraces. Some deposits include interbeds of sand and minor gravel and boulder-size erratics. Terrace surfaces are modified by late Wisconsin outburst flood waters and recent fluvial processes.

Qglf

Glaciolacustrine deposits and outburst flood deposits, undivided (Pleistocene)--Layers of graded and laminated (varved) silt and fine sand rhythmically alternating with layers of typically cross-bedded coarse sand and fine gravel. Silt and fine sand were deposited in a late Wisconsin glacial lake occupying the Pend Oreille River valley (E. P. Kiver, EWU, oral commun., 1988); coarse sand and fine gravel were deposited by pulses of outburst flood water from glacial Lake Missoula into this glacial lake.

Qgd

Drift (Pleistocene)--Unstratified and stratified deposits consisting of varied amounts of clay, silt, sand, gravel, and boulders deposited directly by glacial ice or by water emanating from the ice. The unit includes glacial outwash and till of late Wisconsin age; some deposits are probably of pre-late Wisconsin age (>~35,000 ka; see Richmond and Fullerton, 1986). In some areas the unit contains thin-bedded glaciolacustrine sediments and modern alluvium. In the upper reaches of some valleys, drift deposits probably include contributions from alpine glaciers. On the basis of Miller and Clark's (1975, p. 62) statement:

> "The erosionally resistant north-south belt of ...[rock on the east side of the Colville River valley] appears to have dammed the westward flowing glacial streams and caused deposition of large volumes of glacial debris in the basins east of it",

the Quaternary sediments in the Cottonwood, Sherwood, Thomason, South and North Forks of Chewlah, and the east fork of Bear Creek drainages consist of glacial drift.

Qgo

Outwash (Pleistocene)--Dense, well-sorted, and well-stratified deposits composed mostly of sand and pebble- to cobble-size gravel and smaller amounts of silt and clay; in some areas the outwash deposits are boulder-bearing. The unit probably includes contributions from alpine glaciers in the Calispell Peak area (E. P. Kiver and D. F. Stradling, EWU, written commun., 1987).

Qgt, Qgtp

Till (Pleistocene)--Unsorted and unstratified deposits of pebble- to cobble-size clasts in a matrix of sand and clay; the rounded to subangular clasts are commonly striated. In some places the unit contains boulder-size clasts and minor stratified sediments.

Qgt

Late Wisconsin till--Probably includes contributions from alpine glaciers in the Chewelah Mountain area (E. P. Kiver and D. F. Stradling, EWU, written commun., 1987). A compact lodgment till is exposed along Deer Creek, northwest of Empey Mountain (McLucas, 1980).

Qgtp

Pre-late Wisconsin till--Characterized by a deep-red, highly oxidized soil profile which distinguishes this older till from younger till (Qgt) (E. P. Kiver, EWU, oral commun., 1988). Exposures of older till are found on the southwest flank of Cee Cee Ah Peak, south and west of Marshall Lake, and near the confluence of Tenmile Creek and North Fork of Calispell Creek.

Pliocene to Miocene Sedimentary Rocks

PMcg$_{c}$

Conglomerate of the Chamokane Creek area (Pliocene? to Miocene?)--Poorly lithified to moderately well lithified conglomerate and subordinate sandstone, siltstone, and claystone. Most conglomerate is clast supported, poorly sorted, and poorly stratified to unstratified. Angular to subrounded, randomly oriented, pebble- to cobble-size clasts consist of argillite, siltite, phyllite, schist, quartzite, and slate; granitic (mica-feldspar-quartz) clasts are present in the conglomerate in some places. In some conglomerate the matrix is composed of clay-size illite or hydromica grains and quartz (T. J. Walsh, DGER, written commun., 1988), and granule- to pebble-size, vitreous quartz fragments are present. In some of this conglomerate both the matrix and clasts are pyritized. The lack of carbonate rock, Eocene volcanic rock, and Miocene basalt may be a function of provenance, not age. The unit is poorly exposed, and most outcrops are on southern slopes; unmapped exposures are present on the southern and eastern flanks of Lane Mountain (F. K. Miller, USGS, oral commun., 1988). The unit contains numerous layers and lenses of well-indurated, limonite-stained, and anomalously uraniferous conglomerate, which displays manganese dendrites and coating in a few places.

In sec. 25, T. 30 N., R. 38 E., fine-grained strata of the unit unconformably overlie contorted and brecciated schist of the Precambrian Togo Formation (Yar$_{t}$); bedding is approximately parallel to the present topographic surface. Even though the contact relation with the Miocene basalt flows (Mv$_{gN2}$) is uncertain, Castor and others (1982) believe the unit's age is probably similar to that of the flows. F. K. Miller (USGS, oral commun., 1988) suggests the conglomerate overlies the basalts and could be Pliocene in age. For this report the unit is assigned a Pliocene(?) to Miocene(?) age.

Miocene Volcanic Rocks

Columbia River Basalt Group

$\cancel{M}v_{wp}$

Wanapum Basalt, Priest Rapids Member (middle Miocene)--Flow(s) of fine-grained, typically aphyric basalt; olivine is generally visible in the groundmass. The rock is part of the Rosalia geochemical unit (Anderson and others, 1987, fig. 10), which is characterized by a high TiO_2-low MgO composition (Swanson and others, 1979b). Flows of the Priest Rapids Member are reversely magnetized. The unit is exposed southeast of Eloika Lake, where its thickness is unknown. Flows of the Priest Rapids Member were erupted about 14.5 m.y. ago (Beeson and others, 1985; Reidel and Fecht, 1987).

$\cancel{M}v_{gN2}$

Grande Ronde Basalt, magnetostratigraphic unit N2 (lower to middle Miocene)--Flows of black to dark-gray, fine-grained basalt chiefly composed of dark-brown glass, plagioclase, pyroxene, minor olivine, and abundant disseminated magnetite and/or ilmenite. The rock is aphyric to slightly phyric; it contains sparse plagioclase microphenocrysts. Plagioclase-clinopyroxene clots are commonly visible in hand sample. The dense to slightly vesicular flows are of normal magnetic polarity. Chemically, flows of the Grande Ronde Basalt are tholeiitic basalt (basaltic andesite). Major oxide and trace element data for a sample taken south of Waitts Lake are given in Tables 2 and 3 and indicate the rock is part of the low-MgO Grande Ronde chemical type of Swanson and others (1979a, table 2).

Flows of the Grande Ronde Basalt were erupted between about 15.5 m.y. and about 16.5 m.y. ago (Beeson and others, 1985; Reidel and Fecht, 1987). In the map area flows are restricted to the Colville River drainage below elevations of about 760 m. A well in sec. 30, T. 31 N., R. 41 E., penetrated 42 m of basalt (Miller and Clark, 1975). The contact relation between the Grande Ronde Basalt and the conglomerate of the Chamokane Creek area ($\cancel{P}\cancel{M}cg_c$) is unknown.

Eocene Sedimentary and Volcanic Rocks

Ecg_t, Ec_t

Tiger Formation (lower to middle Eocene)--Continental conglomerate, conglomeratic sandstone, sandstone, siltstone, and shale. Rocks range from well indurated to friable. The unit is distinguished from glacial sedimentary deposits by the degree of induration (Castor and others, 1982). The formation was deposited in an alluvial fan to braided-fluvial environment (Gager, 1984; Harms, 1982).

Except for the exposures 16 km due north of Chewelah, the Tiger Formation is confined to the Pend Orielle River valley in the Chewelah and in the Colville 1:100,000-scale quadrangles. Castor and others (1982) and Gager (1983) subdivided the formation into three and eight members, respectively, but for this report, only the distribution of the conglomerate (Ecg_t) and fine-grained rocks (Ec_t) is delineated on Plate I.

Coarse-grained and fine-grained rocks commonly interfinger and have both conformable and unconformable contacts. The thickness of the formation in the Pend Oreille River area ranges from about 100 m to about 1,200 m, and the strata everywhere dip west (10° to 30°). Along Cliff Ridge about 16 km north of Chewelah, approximately 400 meters of east-dipping strata are assigned to the Tiger Formation (Gager, 1983).

In the Pend Oreille River valley the Tiger Formation unconformably overlies Precambrian metasedimentary and metavolcanic rocks and Paleozoic metasedimentary rocks in the upper plate of the Newport fault. In the Cliff Ridge area the conglomerate unconformably overlies Precambrian metasedimentary and metavolcanic rocks and Paleozoic metasedimentary rocks in the upper plate of the Jumpoff Joe fault.

Palynomorphs indicate an age of early to middle Eocene (Harms, 1982) for the formation in the Pend Oreille River valley; clasts of Sanpoil Volcanics indicate a post-Sanpoil age for at least part of the formation. In the Cliff Ridge area clasts of possible Tertiary volcanic rock indicate a Tertiary age; Miller and Clark (1975) assign a Tertiary age to the conglomerate on the basis of the unconformity at the base of the unit.

Ecg_t

Conglomerate--Polymictic to locally monomictic, clast- and matrix-supported conglomerate that is typically well indurated, poorly sorted, and poorly stratified. Angular to subrounded clasts are mostly of cobble to boulder size, but clasts range down to sand. The degree of roundness typically increases with clast size. The lithology of the clasts indicates that most clasts were locally derived. In the Pend Oreille River valley clasts consist of metasedimentary rocks of the Middle Proterozoic Belt Supergroup, Paleozoic metasedimentary rocks, Cretaceous granitic rocks, and the Eocene Sanpoil Volcanics; some exposures of the uppermost part of this unit contain clasts derived from older Tiger strata (Gager, 1982, 1983; Harms, 1982) and from tectonically deformed rocks of the Newport fault zone (Gager, 1984). In the Cliff Ridge area, clasts consist predominantly of biotite-hornblende granitic rocks, dolomite, and greenstone, as well as subordinate limestone, argillite, quartzite, vein(?) quartz, and Tertiary(?) volcanics (Gager, 1983). Paleocurrent data indicate a western provenance for clasts in the Cliff Ridge area. The unit includes some conglomeratic sandstone and siltstone in the Pend Oreille River valley and some siltstone with coal-like laminae in the Cliff Ridge area.

Ec_t

Fine-grained rocks--Fining-upward sequence of well-sorted, well-stratified sandstone, siltstone, and shale. Sandstone is typically coarse to fine grained and polymictic; in some places it is cross-stratified. Most siltstone and shale are laminated and have abundant thin seams or laminae of carbonaceous material and plant fragments and impressions. In some places the fine-grained rocks are tuffaceous. The fine-grained rocks contain minor conglomeratic sandstone and conglomerate.

Evd_s

Sanpoil Volcanics (Eocene)--Massive, porphyritic dacite flows and flow breccias and some discontinuous intercalated layers of sedimentary rocks. Exposures are restricted to the east side of the Pend Oreille River valley. Flow rock is typically gray or brown but is purple and green in some places; basal parts of flows are dark gray to black. Most flow rock consists of phenocrysts, locally glomeroporphyritic, of hornblende ($\leq$8 mm) and biotite ($\leq$4 mm) in a dull, trachytic groundmass. The groundmass is composed of hornblende and plagioclase (An_{30-50}) microlites in a mesostasis of microcrystalline feldspar and devitrified glass; chilled basal rock consists of hornblende and biotite phenocrysts in a groundmass of pyroxene, hornblende, and biotite microlites in a mesostasis of microcrystalline plagioclase (An_{30-50}) and devitrified glass (Miller, 1974a). The Sanpoil Volcanics unconformably underlie the Tiger Formation (Ecg_t) and unconformably overlie Precambrian metasedimentary rocks, except in sec. 9, T. 33 N., R. 44 E. where flow rock overlies Eocene tuff (Evt). Flows and flow breccias dip to the west, and in some places the flows have a minimum preserved thickness of 150 m (Pearson and Obradovich, 1977). A few small hypabyssal bodies, considered equivalent to the flow rock, intrude Precambrian metasedimentary rocks.

The Sanpoil Volcanics are Eocene; dacite flows and flow breccias yielded K-Ar biotite and hornblende ages of 50 Ma and 51 Ma, respectively (no. 2, Table 1). These rocks were originally named the Pend Oreille Andesite by Schroeder (1952), but Pearson and Obradovich (1977) correlated the Pend Oreille Andesite with the Sanpoil Volcanics of Muessig (1962) (Republic 1:100,000-scale quadrangle) on the basis of their similar age, composition, and stratigraphic position.

Eva

Andesitic rocks in the Colville Valley (Eocene)--Chiefly porphyritic andesite flows and flow breccias and some intercalated sedimentary rocks and pyroclastic rocks. Andesitic rock is exposed in the Waitts Lake-Long Prairie area (DGER mapping, this report), about 4 km southwest of Chewelah, and on the eastern flank of Dunn Mountain. In the Waitts Lake-Long Prairie area, unaltered flows and flow breccia are dark gray to black; weathered and altered (deuteric ?) rock is purple or green, and in some exposures the rock is bleached to pale tan. Phenocrysts consist of hornblende, plagioclase, orthopyroxene, clinopyroxene, and sparse olivine in a groundmass composed of more than 50 percent plagioclase; the remainder of the groundmass is composed of an unidentified mineraloid, devitrified glass, and opaque minerals (DGER mapping, this report; F. K. Miller, USGS, written commun., 1990). Some of this rock is probably dacitic. Intercalated sedimentary rocks include tuffaceous sandstone and shale and minor air-fall(?) tuff. Sandstone is fine grained and well bedded (2.5-20 cm thick); the light-gray to pale-green, greasy, and fissile shale contains leaf impressions in many places; Glover (1936, 1941) reports that a 1.2-m-thick seam of subbituminous coal was exposed in the workings of the Colville Valley mine in sec. 28, T. 31 N., R. 40 E.. These mine workings are now inaccessible, but two seams of amber-bearing, thinly laminated coal interbedded with shale are exposed near the workings (DGER mapping, this report).

The porphyritic rock exposed 4 km southwest of Chewelah is andesite (Tables 2 and 3). Phenocrysts of olivine, hornblende, biotite, clinopyroxene, and orthopyroxene are in an aphanitic groundmass composed of plagioclase and pyroxene microlites in a mesostasis consisting of about 50 percent plagioclase, the remainder consisting of unidentified material, partially devitrified glass, and opaque minerals (DGER mapping, this report; F. K. Miller, USGS, written commun., 1990; Miller and Clark, 1975). The rock may be either extrusive or hypabyssal, but neither flow structure nor layering is apparent. If the rock is extrusive and horizontal, then about 70 meters of andesitic rock are preserved (Miller and Clark, 1975). The andesitic rock in sec. 16 on the eastern flank of Dunn Mountain is a vent agglomerate (R. G. Yates, USGS, retired, written commun., 1986).

Andesitic rocks in the Colville Valley are assigned an Eocene age on the basis of their similarities to the Sanpoil Volcanics (Evd_s) exposed about 16 km southwest of the map area in the Enterprise Valley.

Evt

Tuff (Eocene)--Tuff and tuffaceous shale (Pearson and Obradovich, 1977). Light-gray to pale-tan, thin- to medium-bedded quartz-latite tuff that consists of euhedral biotite, angular quartz, plagioclase, and altered K-feldspar enclosed in a groundmass of clay. The unit is exposed east of the Pend Oreille River valley in sec. 9, T. 33 N., R. 44 E. An 8-m thick section is exposed, but neither the upper nor lower contact is exposed. The tuff is considered Eocene on the basis of a K-Ar biotite age of 53 Ma (no. 3, Table 1). The section of tuff in the map areas resembles the O'Brien Creek Formation present 65 km to the northwest in the Colville 1:100,000-scale quadrangle (Pearson and Obradovich, 1977). R. G. Yates (USGS, retired, written commun., 1986) mapped a small exposure of tuff on the eastern flank of Dunn Mountain in sec. 16, T. 33 N., R. 39 E.

Metasedimentary and Metavolcanic Rocks

Paleozoic to Precambrian Metasedimentary Rocks

Pzcb

Carbonate rocks, undivided (Paleozoic)--Dolomite and limestone in small and scattered outcrops restricted to areas southwest of Bayley Lake and a belt herein called the Valley-Springdale trend extending from about 3 km southeast of Valley to just north of Springdale.

Southwest of Bayley Lake, the unit consists of extremely brecciated, white, gray, and pink dolomite that is fetid, fine to medium grained, and typically recrystallized (DGER mapping, this report). The breccia is healed with calcite, contains cross-cutting calcite veins, and has a crude foliation that strikes northeast and dips northwest. In some places the rock is silicified and contains bull-quartz veins.

The Valley-Springdale trend consists mostly of limestone and dolomite. Miller and Clark (1975) conclude the rocks are not distinctive enough to be assigned to established units or to define a new unit, but several workers have observed that the western part consists of limestone and the eastern part consists of mostly dolomite with minor phyllite (Howd, 1956; Mills, 1962). This stratigraphic succession may correspond to the Carboniferous carbonate rocks of Limekiln Hill (Ccb, mostly limestone) found north of Springdale and the Mississippian-Devonian carbonate rocks east of Chewelah (MDcb, dolomite and subordinate slate) found between Valley and Chewelah.

Pzmm, $Pzcb_2$, $Pzcb_1$

Rocks of Gardiner Creek (Paleozoic)--A package of dolomite and phyllite exposed north of Jared on both sides of Gardiner Creek and extending northward into the Colville 1:100,000-scale quadrangle. Three units comprise the rocks of Gardiner Creek: a phyllite and quartzite unit, an upper dolomite unit, and a lower dolomite unit.

Pzmm

Phyllite and quartzite unit--About 60 percent medium- to dark-gray phyllite and 40 percent quartzite that has minor interbedded dolomite, siltite, and hornfelsed rock. The unit is poorly exposed, but phyllite apparently occurs in zones as much as 60 m thick alternating with zones of quartzite typically <30 m thick (Miller, 1974b). Phyllite is indistinctly bedded, and quartzite is massive to thick bedded. Most quartzite is medium grained, vitreous, and white, but some is dark brown to dark gray and has abundant impurities; most impure quartzite contains interbeds of brown and gray, sandy dolomite. Siltite is chiefly dark gray, and hornfelsed rock is green and gray and banded to poorly laminated (DGER mapping, this report). As much as 730 meters of this unit are exposed in the map area (Miller, 1974b).

Even though all contacts are faults, Miller (1974b) considers the phyllite and quartzite unit younger than the dolomite units. The unit is assigned a Paleozoic age on the basis of its association with the two dolomite units and on its dissimilarity to the Precambrian metasedimentary rocks in the area.

$Pzcb_2$

Upper dolomite unit--Chiefly medium-gray to pale-yellow-tan dolomite interbedded with medium- to dark-gray dolomite that is typically recrystallized, brecciated, and recemented (Miller, 1974b). Most bedding is destroyed but where preserved, it averages about 0.6 m thick. About 300 meters of this unit are exposed in the map; upper and lower contacts are faults.

Pzcb$_1$

Lower dolomite unit--White, pale-gray, and pale-yellow-tan dolomite interbedded with medium- to dark-gray dolomite. The dolomite is finely to coarsely recrystallized, brecciated, and recememted. Where bedding is preserved, it averages about 0.6 m thick. Even though the lower dolomite unit appears to contain fewer dark interbeds, the two dolomite units may actually be one unit (Miller, 1974b). The upper contact is a fault everywhere in the map area, and the lower contact is not exposed, but near the contact with the Addy Quartzite (ЄZq$_a$), the two rock types can be located within 30 m of each other (Miller, 1974b). Float in the intervening covered area consists of coarse, rounded quartz grains surrounded by a dolomitic matrix; the dolomite content of the matrix decreases as the Addy Quartzite is approached, suggesting that the contact may be gradational (DGER mapping, this report). However, the contact may be a fault (F. K. Miller, USGS, written commun., 1990).

The dolomite units of Gardiner Creek are assigned a Paleozoic age because they probably conformably overlie the Addy Quartzite (ЄZq$_a$) and are dissimilar to the Precambrian metasedimentary rocks in the area.

Ccb

Carbonate rocks of Limekiln Hill (Carboniferous)--Limestone, dolomitic limestone, and dolomite characterized by intervals of chert beds and nodules. These rocks are light to medium gray, blue-gray, and pale yellow-tan on fresh surfaces and light gray to pale yellow-tan on weathered surfaces. Most of these rocks are fine to medium grained, but some are coarsely crystalline or aphanitic. Fossiliferous zones are found throughout the unit. Bioclastic breccias are present in some places, but most bioclastic rock is recrystallized and poorly preserved. Most rocks are fetid and contain calcite stringers and pods. Some dolomitic limestone is laminated, but bedding in this unit ranges between 0.6 m and 1 m thick. Some thicker beds are probably bioclastic zones replaced by chert; where chert beds are lacking, carbonate rock appears massive. Chert beds range from 5 cm to 8 cm thick. Chert is black, gray, and white on fresh surfaces, but because much of the chert weathers to the same colors as the carbonate rock, it is not easily distinguished on weathered surfaces.

These rocks are exposed north and south of Springdale. The upper contact is the Jumpoff Joe fault; the unit is the youngest metasedimentary rock unit cut by the Jumpoff Joe fault in the map area. Miller and Clark (1975) suggest the unit conformably overlies the upper unit of the Mississippian-Devonian carbonate rocks east of Chewelah (MDcb$_3$), even though the base of the unit is nowhere exposed.

The carbonate rocks of Limekiln Hill are assigned a Carboniferous age (this report) on the basis of conodonts (Table 4) and macrofossils (Enbysk, 1954; McLaughlin and Simons, 1951; Miller and Clark, 1975). However, the rocks are probably no younger than Late Mississippian (Gheddida, 1988; A. G. Harris, USGS, written commun., 1990).

MDcb$_3$, MDcb$_2$, MDcb$_1$

Carbonate rocks east of Chewelah (Lower Mississippian? to Upper Devonian?)--Three units consisting mostly of dolomite with some slate comprise this sequence (Miller and Clark, 1975). The carbonate rocks are massive and coarsely recrystallized near the contact with the Flowery Trail Granodiorite (JTRii$_f$). The sequence is restricted to a belt extending from just east of Chewelah south to Springdale.

Westernmost exposures of the carbonate rocks east of Chewelah are sheared and brecciated along the Jumpoff Joe fault. In some places the lower unit is brecciated near the inferred fault contact with the Addy Quartzite (ЄZq$_a$) and along the northern part of the inferred fault, the breccia is recrystallized, suggesting that brecciation is older than the Flowery Trail Granodiorite (JTRii$_f$).

No fossils have been found in the carbonate rocks east of Chewelah. Miller and Clark (1975) suggested the fossiliferous Carboniferous carbonate rocks of Limekiln Hill (Ccb) conformably overlie the carbonate rocks east of Chewelah, providing the minimum age of Early Mississippian for the rocks east of Chewelah. The maximum age of Late Devonian is based on fossils from isolated outcrops of carbonate rocks near Valley (Dcb) (Miller and Clark, 1975).

MDcb$_3$

Upper unit--A heterogeneous mixture of light-colored dolomite, maroon slate, and gradations between the two rock types. The lower part is chiefly light-gray and pale-tan dolomite that weathers pale orange. Bedding ranges from 5 cm to 3 m thick, and textures range from sugary to aphanitic. About 15 m above the base of the unit, well-laminated maroon slate and gray-green, argillaceous dolomite are interbedded with the light-colored dolomite. The maroon slate increases in abundance upward and typically contains laminae of dolomite. A zone, about 30 m thick, of thin-bedded, maroon slate is present about 60 m to 90 m above the base of the unit; this slate zone grades upward and downward into pale-green argillite. Above the maroon slate zone, pale-green argillite grades into light-gray to pale-tan dolomite similar to dolomite in lower part of unit. The upper contact is not exposed, but the upper unit is probably conformably overlain by the Carboniferous carbonate rocks of Limekiln Hill (Ccb)(Miller and Clark, 1975). About 150 to 180 meters of this unit are exposed.

MDcb$_2$

Middle unit--Homogeneous, white to light-gray, coarse-grained dolomite. Bedding is poorly defined, but it averages 1 m thick; some rock appears massive but is actually thinly laminated. Large ooliths and pisoliths are abundant in the lower 3 m to 6 m of unit; oolith-bearing beds typically alternate with beds exhibiting algal structures. White dolomite of this middle unit is conformably overlain by the light-gray and cream dolomite of the upper unit (MDcb$_3$). Between 150 and 200 meters of the unit are exposed (Miller and Clark, 1975).

MDcb$_1$

Lower unit--Dark-gray dolomite and abundant dolomitic conglomerate, a few zones of light-gray, mottled dolomite, and rare argillaceous dolomite. The unit is discontinuously exposed. Bedding is typically well defined and ranges from about 5 cm to 1.5 m thick. The texture ranges from aphanitic to coarsely crystalline, but most rock is fine grained. The conglomerate is composed of angular to sightly rounded clasts of dolomite in a dolomitic matrix. Beds (<0.3 m thick) and irregular lenses of ooliths are present throughout the unit. Curved chips of coarse-grained dolomite may represent poorly preserved pelmatozoan or brachiopod debris. Dark dolomite of this lower unit is sharply but conformably overlain by white dolomite of the middle unit (MDcb$_2$); the lower contact is not exposed, but it is probably everywhere a fault. The exposed thickness of the lower unit is about 180 m to 210 m (Miller and Clark, 1975).

Dcb

Carbonate rocks near Valley (Upper Devonian)--Fine- to coarse-grained, light- to medium-gray limestone and light- to medium-gray, pale-yellow-tan, and pink dolomite. Some rocks are bioclastic, and most limestone is punky due to solution cavities. Bedding features are typically not discernible.

Limited exposures of the unit are found east of Valley. The upper part of the unit is truncated by the Jumpoff Joe fault, and the lower part is covered. Contact relations with the other Paleozoic metasedimentary rock units in the area are unknown, but the carbonate rocks near Valley do contain Late Devonian macrofossils (Miller and Clark, 1975) and conodonts (Table 4).

Omm_l

Ledbetter Slate (Middle to Lower Ordovician)--Calcareous and noncalcareous, fine-grained, phyllitic argillite and slate that contains subordinate dark-gray to black siltite, fine-grained quartzite, and impure limestone (DGER mapping, this report). Argillite and slate are black and dark gray to light gray on fresh surfaces and are light gray, olive-gray, and pale yellow-tan on weathered surfaces. Darker rock may be graphitic. Bedding is rarely visible; where bedding can be seen, the pervasive fracture cleavage is parallel to it or cuts it at low angles. Carbonate content of the rock increases downward toward the contact with the underlying Metaline Formation ($O€cb_m$). The quartzite contains abundant pods of white quartz. In some places the formation is silicified near faults; much of the rock is hornfelsed near granitic rocks but is rarely coarsely recrystallized or micaceous.

Dark-gray to black, laminated to thin-bedded chert is included in the Ledbetter Slate for this report. Chert, exposed in sec. 13, T. 34 N., R. 38 E., contains some limestone beds and abundant secondary quartz veins (DGER mapping, this report). The chert is similar to a Ordovician-Cambrian chert unit mapped west of the map area by Campbell and Raup (1964); Joseph (in press) includes the chert unit in the Ledbetter Slate in the Nespelem 1:100,000-scale quadrangle.

The formation restricted to northwestern corner of the map area. The upper part of the formation is not exposed in the map area. The formation conformably overlies the Metaline Formation ($O€cb_l$, $O€cb_d$) with a gradational contact. This contact is a 30-m-thick transition zone consisting of thin-bedded (<1.5 cm) to laminated, slatey and phyllitic, impure limestone interbedded with phyllitic argillite or slate; quartz and calcite veins are present in much of this zone. The thickness of the formation is varied due to shearing and folding, but Snook (1981) estimated a maximum apparent thickness of about 1,000 m.

The Ledbetter Slate is Middle to Early Ordovician in age, on the basis of graptolites from several localities in Stevens County (Snook and others, 1981; Mills, 1977; Park and Cannon, 1943). No graptolites have been found in the map area.

$O€cb_m$, $O€cb_d$, $O€cb_l$

Metaline Formation (Middle Ordovician to Lower Cambrian)--In the map area, the upper part of the formation is dominated by dolomite, and the lower part is dominated by limestone. Where possible, the formation is subdivided into an upper dolomite unit and a lower limestone unit; elsewhere, the formation is undivided. The Metaline Formation was named by Park and Cannon (1943) for exposures in northern Pend Oreille County, but in central and southern Stevens County, these carbonate rocks were named the Old Dominion Limestone by Weaver (1920). Because both of these formations occupy the same stratigraphic position and are laterally correlative (Lucas, 1980; Mills, 1977; Miller and Clark, 1975; Snook and others, 1981), use of the name Old Dominion Limestone is abandoned in this report.

The estimated thicknesses of the Metaline Formation, in and near the map area, are varied. Evans (1987) estimates the section west of Stensgar Mountain is about 1,500 m thick. Snook and others (1981) conclude the formation extending westward from the flank of Dunn Mountain into the adjacent Nespelem 1:100,000-scale quadrangle is about 900 m thick. Miller and Clark (1975) estimate the thickest partial section southeast of Springdale is about 760 m thick. Snook (1981) reports the limestone unit is about 600 m thick and the dolomite unit is about 200 m thick, yielding a total thickness of 800 m for the Metaline Formation east of Arden. Bennett (1944) estimates the dolomite is about 1,100 m thick northwest of Dunn Mountain and about 600 m thick on the ridge west of Addy, where about 120 m of limestone lies below the dolomite unit.

On the basis of conodonts and fragments of Anatolepis (the oldest known fish), the Metaline Formation ranges in age from Middle Cambrian to Middle Ordovician (Repetski, 1978; Repetski and others, 1989). The early Middle Ordovician age is based on the fossil assemblage in the upper 30 m of the formation. The uppermost Metaline Formation and the basal part of the Ledbetter Slate probably interfinger (Repetski and others, 1989).

O€cb_m

Metaline Formation, undivided--Limestone and dolomite and lesser interbedded argillite, shale, and slate. The upper part is mostly massive or thin- to thick-bedded dolomite. Most dolomite is white or light to dark gray, but some is black, tan, and pale tan or has light and dark bands. In some places the dolomite is interbedded with dark-colored slate or shale and massive, blue-gray limestone. The lower part is mostly thin- to thick-bedded, gray to black, fine-grained limestone that has many argillaceous or shaley interbeds. Argillaceous interbeds are typically wavy and weather yellow-brown. Shaley interbeds are black to dark-gray and typically $\leq$0.3 m thick. Lindsey (1988) places the lower contact on the west flank of Huckleberry Mountain at the base of the lowest limestone bed that is more than 1 m thick and that overlies interbedded argillite, siltite, and quartzite of the upper unit of the Addy Quartzite (€Zq_4). The small exposure of extremely brecciated, light- to dark-gray dolomite about 5 km northwest of Chewelah is tentatively included in the Metaline Formation(?) for this report on the basis of its lithology.

O€cb_d

Dolomite unit--Fine- to medium-grained, white, gray, and tan dolomite. Most dolomite is massive to thick bedded north of Stranger Creek, but it is progressively thinner bedded southward (Lucas, 1980). Bedding is marked by light- and dark-gray bands 1 to 20 m thick. In some places dolomite contains dark shale, oncolite, and pisolite interbeds; west of Dunn Mountain, the dolomite contains chert nodules and stringers. The unit consists of gray to white, coarsely recrystallized dolomitic marble near granitic rocks. Some of the marble has closely spaced light and dark bands similar to the zebra rock described by Park and Cannon (1943, p. 42). The contact with the overlying Ledbetter Slate (Omm_l) is gradational; the contact with the underlying limestone unit is sharp but conformable.

O€cb_l

Limestone unit--Gray to blue-gray limestone and dolomitic limestone that contains wavy, yellow-brown argillaceous layers and seams; thin, slatey or shaley interbeds are present throughout the unit. Most limestone is thin bedded, but some is thick bedded to massive or recrystallized. The limestone unit conformably overlies the Maitlen Phyllite (€ph_m) or Addy Quartzite (€Zq_a). Limestone grades downward into argillaceous or sandy limestone that contains argillaceous interbeds, which, in turn, grades into the argillaceous sequence of the underlying formation.

€ph_m

Maitlen Phyllite (Lower Cambrian)--Massive, brown to gray, mottled argillite grading downward into brown to tan, micaceous argillite on the west flank of Dunn Mountain (Lindsey, 1988). Another 90 m thick section of argillite is south-southwest of Addy in sec. 23, T. 33 N., R. 39 E. (R. G. Yates, USGS, retired, written commun., 1986). On the flank of Dunn Mountain the formation is 200 m thick, and the lower contact with the Addy Quartzite (€Zq_a) is conformable; the contact is placed at the base of the lowest zone of micaceous argillite more than 10 m thick. The upper contact, with the Metaline Formation (O€cb_m, O€cb_l), is gradational. The transitional zone consists of layers and lenses of limestone interbedded with argillite, and the contact is placed at the top of the argillite layer underlying the first limestone bed more than 0.5 m thick.

The Maitlen Phyllite is shown on Plate I only where the rocks directly overlying the Addy Quartzite (€Zq_a) have no quartzite component or where quartzite is present only as thin stringers (this report). Yates (1976) notes that the Maitlen Phyllite thins from north to south, and Lindsey (1988) suggests the Maitlen Phyllite and the uppermost 150 m of the Addy Quartzite interfinger between Dunn Mountain and

Huckleberry Mountain. The upper part of the Addy Quartzite and the Maitlen Phyllite are both argillaceous, occupy the same stratigraphic position, and are similar in thickness and age. The Maitlen Phyllite is considered Early Cambrian in age based on the presence of paleosponges collected from the formation outside the map area (Dings and Whitebread, 1965; Hampton, 1978).

€Zq_4, €Zq_3, €Zq_2, €Zq_1, €Zq_a

Addy Quartzite (Lower Cambrian to Upper Proterozoic)--The Addy Quartzite is a thick sequence composed dominantly of quartzite but having significant amounts of siltite and argillite in the upper one-third to one-quarter of the formation. The formation is between 1,100 m and 1,450 m thick. Exposures of Addy Quartzite extend from central Stevens County south into northern Lincoln County (Coulee Dam 1:100,000-scale quadrangle); limited exposures are present in southern Pend Oreille County. Figure 4 shows the distribution of the Addy Quartzite in the map area.

Lindsey (1987, 1988) divided the Addy Quartzite on Dunn Mountain, Huckleberry Mountain, and in the Iron Mountains (Fig. 4) into four informal lithostratigraphic units: an upper unit; a coarse unit; a purple-banded unit; and a basal unit. Only the upper two units are present on Wrights Mountain (Fig. 4). Elsewhere in the map area, the formation remains undivided.

The part of the Addy above the lowest horizon containing trilobite body and trace fossils is Lower Cambrian, and at least part of the sequence below the fossil-bearing horizon is Upper Proterozoic. The lowest occurrence of trilobite fossils is at least 50 m above the base of the upper unit (€Zq_4); trilobite remains consist of the trace fossils Rusophycus and Cruziana and body fossils of Nevadella addyensis (Lindsey and others, 1990). Down-section strata, lithologically similar to the fossil-bearing horizon, do not contain trilobite fossils. The Cambrian-Precambrian time boundary is inferred to be at least 500 m below the base of the trilobite-bearing zone (Lindsey and others, 1990).

€Zq_4

Upper unit--Interbedded quartzite, siltite, and argillite. On Huckleberry and Dunn Mountains the lowermost 100 meters of the unit is composed of medium-grained to granular quartzite and interbedded argillite and siltite, overlain by 20- to 30-m-thick argillite zones interlayered with 20-m-thick zones of fine- to medium-grained quartzite. In the Iron Mountains, the upper unit is essentially the same, except that argillite dominates in zones 10 to 20 m thick and quartzite dominates in zones $\leq$15 m thick. Wavy and hummocky bedding, small-scale cross-bedding, and ripple marks characterize the upper part of this unit. This unit is conformably overlain by the Ordovician-Cambrian Metaline Formation (O€cb_m, O€cb_l) or Cambrian Maitlen Phyllite (€ph_m). The lower contact is placed at base of lowest argillite bed that is more 1.5 m thick and that overlies coarse-grained, cross-bedded quartzite. The unit is 250 to 450 m thick, except in the Iron Mountains where the upper part is missing.

€Zq_3

Coarse unit--White, tan, and light-brown, medium-grained to granular quartzite. The rock is typically thin to medium bedded and characterized by small- and medium-scale cross-bedding. Many pebble conglomerate beds ($\leq$10 cm thick) are present in the lower 100 m of this unit. Thin, lenticular beds of argillite and siltite are found throughout the unit; thicker beds ($\leq$50 cm) of finer grained rocks are restricted to the upper half of unit. The thickness of the coarse unit is varied: from 250 m to 400 m on Huckleberry Mountain, 300 m on Dunn Mountain, and $\leq$600 m in the Iron Mountains. The lower contact is placed at the base of lowest, cross-bedded, granular to coarse-grained quartzite bed more than 5 m thick.

$€Zq_2$

Purple-banded unit--White, blue, and lavender, fine- to coarse-grained quartzite characterized by red, purple, and black Liesegang bands and heavy-mineral layers. Liesegang banding is both parallel and transverse to bedding; heavy-mineral layers consist of detrital zircon, rutile, and magnetite or hematite pore fillings and coatings on quartz grains. In some places quartzite contains thin (<2 cm) pebble beds. Purple argillite beds ≤2 m thick are common in the lowermost 50-100 m of the unit; in the remainder of the unit, argillite occurs only as partings and in beds <2 cm thick. Many beds are laminated, and cross-bedding is present throughout the unit. The thickness of the unit is varied: ≤150 m on Dunn Mountain, 200-300 m on Huckleberry Mountain, and 150-200 m in the Iron Mountains. The lower contact is placed at the base of lowest purple-banded quartzite bed more than 2 m thick.

$€Zq_1$

Basal unit--Fine- to medium-grained, vitreous, white quartzite; granular quartzite is present in many places. This quartzite is typically medium to thick bedded; medium- to large-scale cross-bedding and channels are found in some places. Argillite and siltite are rare in this unit. The basal unit rests on strata of the Windermere Group or Deer Trail Group with angular unconformity (Lindsey, 1987). The thickness ranges from 100-150 m on Huckleberry Mountain, to 200 m on Dunn Mountain, to 170-300 m in the Iron Mountains.

$€Zq_a$

Addy Quartzite, undivided--Chiefly quartzite containing abundant siltite and argillite in the upper one-third to one-quarter of the formation. The Addy Quartzite is undivided in the Pend Oreille River area, near Eloika Lake, on The Island, Boudes Hill, Lyons Hill, on Lane Mountain, in the northwest corner of the map area, on the north side of Marble Valley, and in a belt extending from Eagle Mountain southwest to Jumpoff Joe Mountain. These rocks are upgraded to micaceous quartzite, schist, and phyllite near bodies of intrusive rock.

The formation consists of thick-bedded, vitreous, white, light-gray, and pink, fine- to medium-grained quartzite in the Pend Oreille River area and north and west of Eloika Lake (Miller, 1974a, 1974b, 1974c). About 15-30 meters of dark- to light-purple quartzite containing thin pebble beds make up the basal zone of the formation. About 300-450 meters of quartzite are preserved in the Eloika Lake area, where the basal contacts are faults. The rocks are extremely brecciated west of Eloika Lake and west of the Pend Oreille River in the Gardiner Creek area.

On The Island, Boudes Hill, and Lyons Hill the Addy Quartzite is white and gray on fresh surfaces and yellow, orange, and brick-red on weathered surfaces (Knutsen, 1979). Most rock contains heavy-mineral layers, Liesegang banding, or iron-oxide coatings on quartz grains. Most bedding is defined by schistose interbeds and heavy-mineral concentrations. On Lane Mountain, most of the quartzite is thick bedded and well cemented; on the northern flank of the mountain, some quartzite is friable and mottled (Evans, 1987).

In the northwest corner of the map area the uppermost part of the formation is metamorphosed to quartz-mica schist, phyllite, white, gray, and pale-green quartzite, and minor pale-green dolomite or calc-silicate rock (DGER mapping, this report); this upper part may be part of the Maitlen Phyllite ($€ph_m$) (Snook, 1981). This upper part is underlain successively by white, coarse- to medium-grained quartzite; massive, white to pale-pink, medium-grained quartzite; fine-grained, feldspathic quartzite; and red- to purple-banded quartzite and white, medium-grained quartzite. Rocks in this area are folded; small-scale crenulations and medium-scale folds are visible in most exposures. Fold axes trend northeast. Along with the quartz-mica schist and phyllite, the quartzite and calc-silicate rock are cut by a visible northeast-striking and steeply dipping foliation; where bedding is discernible, foliation is nearly parallel to it.

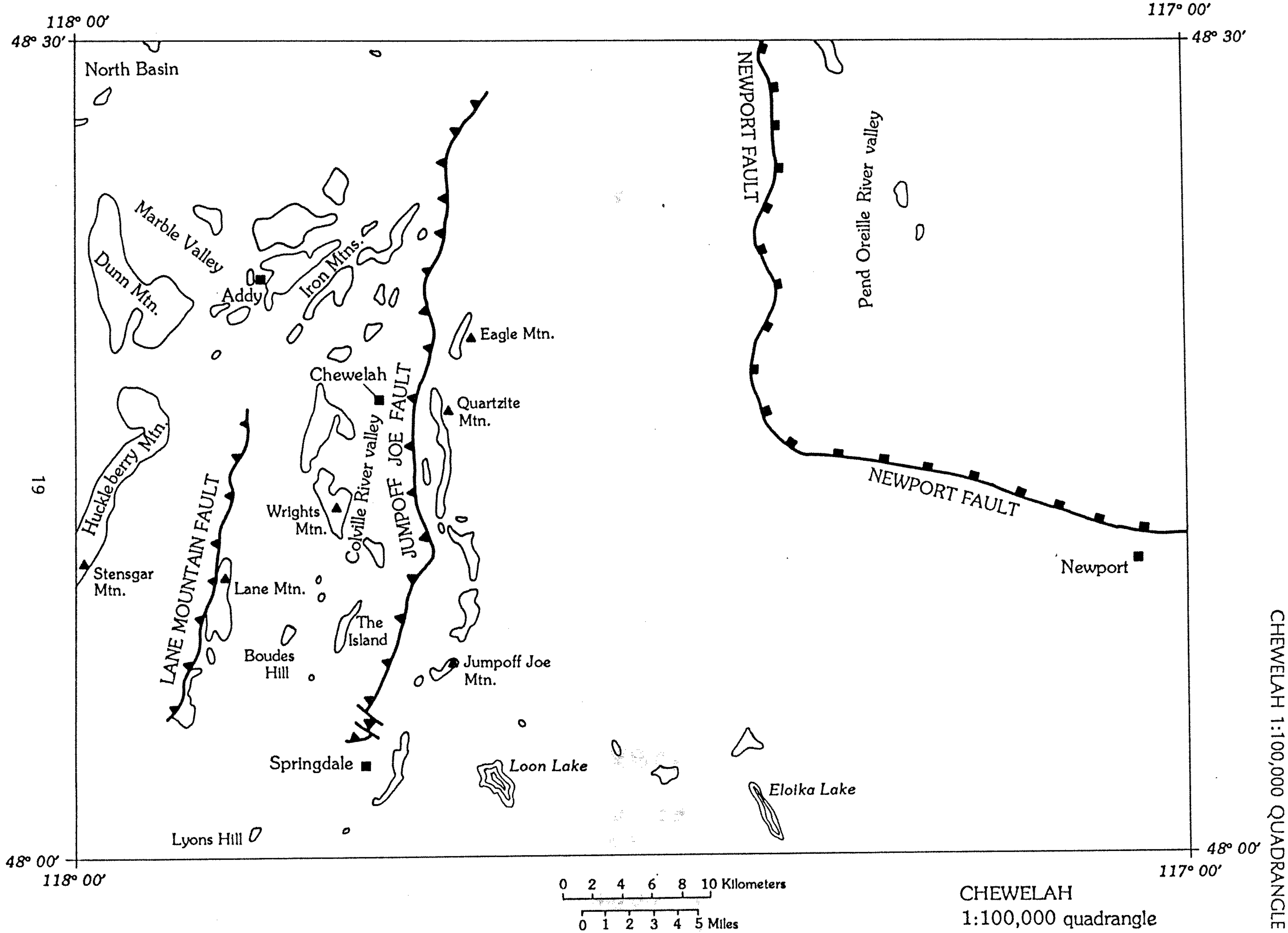


Figure 4. Sketch map showing the distribution of the Addy Quartzite in the Chewelah 1:100,000-scale quadrangle.

On the north side of Marble Valley, the Addy Quartzite includes dark, slightly micaceous siltite and interbeds of calc-silicate hornfels; this rock may be part of the Maitlen Phyllite (€ph_m) (Lucas, 1980). This siltite overlies black, medium-grained quartzite which overlies light-colored, coarser grained, vitreous quartzite that has argillaceous partings. The micaceous siltite is separated from the overlying Metaline Formation (O€cb_l) by about 30 m of cover (DGER mapping, this report); in the covered area float consists of quartzite made up of coarse, rounded quartz grains in a white, carbonate matrix.

In the belt of exposures extending from Eagle Mountain southward to Jumpoff Joe Mountain, the upper part of formation consists of white, tan, brown, and pink, fine- to coarse-grained quartzite and abundant argillite and some argillite interbeds (<3 m). The upper part is $\leq$150 m thick and is underlain by $\leq$150 m of pink, red, purple, and purple-banded, medium- to coarse-grained quartzite; at numerous places along strike, the purple quartzite contains lenses of pebble conglomerate. The purple-tinted rock forms the base of the formation in this area. It rests with angular unconformity on strata of the Belt Supergroup. The total thickness of the formation in this belt is between 200 m and 300 m (Lindsey, 1987); it is not known whether this apparent eastward thinning of the Addy Quartzite is due to facies changes, post-depositional erosion, or structural thinning.

Precambrian Metasedimentary and Metavolcanic Rocks

Windermere Group

In the map area the Windermere Group is composed of two formations: the Huckleberry Formation, consisting of a lower conglomerate member and an upper greenstone member, and the overlying Monk Formation. In some places the conglomerate member of the Huckleberry Formation and the Monk Formation are missing. To the north, in the Colville 1:100,000-scale quadrangle, rocks equivalent to the conglomerate and greenstone members of the Huckleberry Formation are referred to as the Shedroof Conglomerate and the Leola Volcanics (Park and Cannon, 1943). The Monk Formation is known by that name everywhere in northeastern Washington. In the map area, Windermere rocks unconformably overlie rocks of the Middle Proterozoic Deer Trail Group and are unconformably overlain by the Lower Cambrian-Upper Proterozoic Addy Quartzite.

The Late Proterozoic age of the Windermere Group is based mainly on stratigraphic position of the strata and their relation to bounding units. A poorly constrained Sm-Nd isochron age of 762 Ma (Table 1) and poorly constrained K-Ar whole-rock ages ranging from 734 Ma to 862 Ma (Table 1) from metavolcanic rocks of the greenstone member of the Huckleberry Formation also imply a Late Proterozoic age for Windermere strata.

Zmm_m

Monk Formation (Upper Proterozoic)--Mostly slatey argillite and some dolomite, conglomerate, and siltite. This formation is characterized by its heterogeneity and pronounced lithologic variation over short distances (Miller and Clark, 1975). Slatey argillite is finely laminated to thin bedded and gray, brown, or red or maroon. Carbonate-bearing siltite and argillite are abundant in the lowermost part of the unit but decrease in abundance upward so that the uppermost part is carbonate-free. In some places the lower part of the formation consists of a zone of pale-yellow or gray, recrystallized dolomite that grades upward into slatey argillite. In some places the dolomite zone is separated from the overlying argillite by a zone of yellow-brown, pisolitic carbonate rock, and in some places the dolomite zone is separated from the unconformably underlying Huckleberry Formation (Zmv_h) by a zone of carbonate-bearing argillite and conglomerate. Conglomerate is both matrix- and clast-supported and is polymictic; clasts are subangular to subrounded pebbles and cobbles of metavolcanic rock, quartzite, siltite, argillite, and metacarbonate rock. The matrix is typically fine grained, chloritized, and carbonate-bearing. In some places the unit includes beds of pale-green siltite.

No complete section of the Monk Formation is known in the map area. The most extensive exposures are in the Iron Mountains, from Addy Mountain southwestward. There, the formation has a maximum thickness of 75 m (Lindsey, 1988), is unconformably overlain by the Addy Quartzite (€Zq_1), and consists of a lower zone about 45 m thick of dolomite overlain by thin-bedded slatey argillite (Miller and Clark, 1975). Southwest of Addy Mountain, a zone of carbonate-bearing argillite and pebble conglomerate underlies the dolomite. Conglomeratic strata may include some intercalated metavolcanic layers (F. K. Miller, USGS, oral commun., 1989).

North of Lane Mountain, in sec. 11, T. 31 N., R. 39 E., angular blocks of carbonate rock, 10 cm to 150 m in diameter, are in an argillite matrix (F. K. Miller, USGS, written commun., 1990). In secs. 10 and 15, T. 31 N., R. 39 E., the formation consists of slate and argillite that grades upward to matrix-supported conglomerate with pebble- to cobble-size clasts. Conglomeratic rock is overlain by fine-grained, dark-colored dolomite. The exposed section is about 490 m thick (Evans, 1987).

Assignment of the phyllitic rock south of Bayley Lake (sec. 7, T. 33 N., R. 41 E.) to the Monk Formation is based on its stratigraphic position above the Huckleberry Formation (Zmv_h) and below the Addy Quartzite (€Zq_a). West of Bayley Lake (secs. 1 and 12, T. 33 N., R. 40 E.), the formation consists of about 30 m of pale-tan dolomite faulted over about 45 m of maroon argillitic dolomite and carbonate-bearing argillite; about 6 m of conglomerate and pebbly argillite lie near the top of the exposed section. Dolomite may be part of the Stensgar Dolomite (Miller and Clark, 1975).

Southwest of Chewelah (secs. 22 and 34, T. 32 N., R. 40 E.), the Monk Formation is unconformably overlain by the Addy Quartzite (€Zq_a) and faulted against the Huckleberry Formation (Zmv_h, Zcg_h) (Miller and Clark, 1975). In sec. 22 it consists of gray argillite and siltite and interbeds of gray dolomite. In sec. 34, the formation consists of poorly exposed, light-colored argillite containing lenses or discontinuous layers of pale-tan to pale-yellow-tan dolomite; these lenses may be blocks similar to those north of Lane Mountain (F. K. Miller, USGS, written commun., 1990). Much of the argillite is Liesegang banded; calcite and quartz veins cut the dolomite. In some places the dolomite contains rounded features that may be pisoliths (DGER mapping, this report).

Just west of Waitts Lake the formation is composed of dark-green, clast-supported conglomerate (DGER mapping, this report). Subangular to subrounded clasts consist of metasedimentary rocks, metavolcanic rocks (greenstone and andesite-like rock), and foliated gneissic rock. The matrix consists mostly of chlorite, calcite, and quartz.

Zmv_h, Zcg_h

Huckleberry Formation (Upper Proterozoic)--The Huckleberry Formation consists of an upper sequence of metavolcanic rocks and a lower sequence of conglomeratic rocks. In many places the conglomeratic rocks are absent or are present only as thin layers in the lower part of the metavolcanic rock sequence. For this report, the two sequences are referred to as the greenstone member and conglomerate member of the Huckleberry Formation following the usage of Campbell and Loofbourow (1962).

Zmv_h

Greenstone member--Light- and dark-green flows, volcanic breccias, and tuff. Individual flows and breccia units are traceable only over short distances; outcrops are massive and resistant. Where sheared, the rocks are phyllitic or schistose and have well-developed cleavage. Major- and trace-element geochemistry is consistent with that of a tholeiitic basalt extruded in a continental rift setting (Devlin and others, 1985).

Most flow rock is fine grained to aphanitic, and some is porphyritic. In some places the relict primary texture indicates that some rock contained glass and that much of the rock was vesicular. Mafic minerals made up about 50 percent of the rock. Plagioclase phenocrysts make up $\leq$10 percent of the porphyritic rock (Evans, 1987). All these rocks are altered; most minerals are albitized, chloritized, and/or epidotized. However, pyroxene phenocrysts are relatively unaltered (Devlin and others, 1988; Miller and others, 1973). Relict primary minerals are surrounded by a haze of alteration minerals and finely disseminated opaque minerals. In many places flow rock contains amygdules filled with calcite, chlorite, or epidote. Relict primary texture indicates that much of the volcanic rock was hyaloclastite. North of Huckleberry Creek the greenstone member includes a few meters of conglomerate at its base (F. K. Miller, USGS, written commun., 1990).

In the map area, the thickness of the greenstone member is varied, but the member seems to thicken from south to north. The maximum thickness, estimated from outcrop width, is about 650 m (F. K. Miller, USGS, written commun., 1990). The greenstone member is unconformably overlain by the Monk Formation (Zmm_m) or by the Addy Quartzite ($€Zq_a$, $€Zq_1$). Contact with the underlying conglomerate member (Zcg_h) is a bed-by-bed gradation; the contact is placed at the base of the lowest massive flow rock. Where the conglomerate member is absent, the greenstone member unconformably overlies Middle Proterozoic rocks of the Deer Trail Group (Yar_{dt}, Yq_b, Ycb_s, Yar_m).

Zcg_h

Conglomerate member--Diamictite, conglomerate, quartzite, and argillite. Rocks are pale to dark green, gray, gray-green, or black; most rock is phyllitic or schistose and has well-developed cleavage. Diamictite consists of rounded and angular clasts in a matrix of chloritized argillite or siltite. Most angular clasts consist of argillite, siltite, and phyllite, and most rounded clasts consist of quartzite, carbonate, and quartz; clasts are commonly flattened parallel or sub-parallel to cleavage. Most clasts are pebble to cobble size, but larger and smaller clast are locally present. Clasts average about 25 percent of the rock, but the amount ranges from less than 5 percent to more than 65 percent (Aalto, 1971; Evans, 1987). Except for its clast-supported framework, the conglomerate is similar to the diamictite in most respects. Quartzite ranges from well-sorted quartz arenites to poorly sorted lithic wackes; most quartzite is coarse grained and has graded or faintly laminated beds. Argillite is massive or laminated and typically contains dispersed sand grains or larger clasts. Argillite is most abundant near the top of the conglomerate member, where it probably has a tuffaceous component (Campbell and Loofbourow, 1962).

The unit averages about 460 m thick on Huckleberry Mountain. Southeast, east, and northeast of Huckleberry Mountain, the conglomerate member thins to zero. The conglomerate member unconformably overlies strata of the Middle Proterozoic Buffalo Hump Formation or Stensgar Dolomite (Yar_b, Ycb_s).

Zmt_w

Windermere Group, undivided (Upper Proterozoic)--The unit consists of argillite, siltite, conglomerate, and metavolcanic rock and is restricted to the Empey Mountain area (F. K. Miller, USGS, written commun., 1988, 1989). Argillite and siltite are laminated to nonlaminated and typically occur in a sequence of upward-thinning beds. Metavolcanic rock is composed of greenstone and is typically bounded, bottom and top, by conglomerate. Most conglomerate is matrix supported and has rounded to angular clasts. Windermere stratigraphy in the Empey Mountain area is not typical of the group elsewhere in the map area; strata included in this unit may all be part of the Monk Formation (F. K. Miller, USGS, oral commun., 1988).

This unit is unconformably overlain by the Addy Quartzite (CZq_a) and unconformably overlies the Buffalo Hump Formation (Yar_b). On the southern flank of Empey Mountain, the pre-Addy unconformity cuts through this section of Windermere strata.

Deer Trail Group

The Middle Proterozoic Deer Trail Group is a sequence of argillite, siltite, quartzite, and dolomite extending from Chewelah southwestward to the Spokane River beyond the map area. The formations that comprise the Deer Trail Group were defined by Campbell and Loofbourow (1962) for exposures along Huckleberry Mountain. The Deer Trail Group includes, in descending order, the Buffalo Hump Formation, the Stensgar Dolomite, the McHale Slate, the Edna Dolomite, and the Togo Formation.

Yar_b, Yq_b

Buffalo Hump Formation (Middle Proterozoic)--Laterally varied, interfingering argillite and quartzite (Campbell and Loofbourow, 1962). The argillite (Yar_b) consists mostly of argillaceous or slatey rocks, and the quartzite (Yq_b) consists mostly of quartzitic rocks, but both include a range of lithologies.

The Buffalo Hump Formation is unconformably overlain by Windermere Group rocks (Campbell and Loofbourow, 1962; Miller and Whipple, 1989), or the Windermere Group rocks are thrust over the Buffalo Hump Formation (Evans, 1987).

The calculated maximum thickness for the formation in the central part of Huckleberry Mountain is 520 m (Miller and Whipple, 1989) and about 300 m on the hill north of Valley (Miller and Clark, 1975); Campbell and Loofbourow (1962) measured about 300 m of quartzite just north of Huckleberry Creek.

Yar_b

Argillite--Faintly to distinctly laminated argillite, phyllitic argillite, slatey argillite, and slate; siltite is abundant in the transition zone between the argillite and quartzite. Most argillite is gray or green, but some is brown, maroon, black, and tan. In some places the unit is pyritic. Bedding is typically not visible, but most rocks are thinly cleaved.

Along much of Huckleberry Mountain the upper and lower parts of the formation consist of argillitic rock. The argillite in the lower part of the formation appears to thin to the north and south from the center of the mountain range; thinning may be stratigraphic or due to folding, faulting, and poor exposure (Miller and Whipple, 1989). Absence of the argillite in the lower part of the Buffalo Hump Formation north of Huckleberry Creek may be due to faulting, nondeposition, or an internal unconformity in the lower part of the formation.

F. K. Miller (USGS, oral commun., 1988) indicates that the rocks mapped as Buffalo Hump Formation in the Empey Mountain area are not typical of the formation. There, most of the formation is thin-bedded siltite and argillite couplets and only minor quartzite beds.

Yq_b

Quartzite--Quartzite, quartz grit, conglomerate, siltite, and argillite or slate. Most quartzite is vitreous, but some is feldspathic. Most is pale gray, yellow, or light brown, and some is white, maroon, red, green, bluish, and black. Most quartzite is medium grained but ranges from coarse to fine grained and poorly to moderately well sorted. Sedimentary features, including bedding, are poorly defined in much of the quartzite; where bedding is visible, it ranges from <4 cm to 2 m. Quartz grit (angular grains) and quartz-pebble to -cobble conglomerate occur as lenses and thin beds. Clasts are angular to subrounded, and in some places they are stretched and flattened parallel or subparallel to cleavage. Argillaceous, matrix-supported conglomerate is present in some places, but its position in the section is uncertain (F. K. Miller, USGS, written commun., 1990). Gray, laminated argillite or dark, slatey argillite occurs as lenses or interbeds. Quartzite forms zones 1 to 300 m thick in the Buffalo Hump Formation.

Ycb$_s$

Stensgar Dolomite (Middle Proterozoic)--Mostly dolomite, but includes argillite and chert and minor quartzite, siltite, and conglomerate. Most dolomite is light gray, white, pink, or tan on fresh surfaces and pale yellow-tan on weathered surfaces. In some places along strike, maroon dolomite is present in zones of varied thickness. A 50-m-thick zone of gray-weathering dolomite and chert lies about 50 m above the base of the formation; this zone is the only gray-weathering Middle Proterozoic carbonate rock along Huckleberry Mountain. Most dolomite is fine grained to aphanitic, but where the rock is recrystallized, it is massive, white, medium- to coarse-grained dolomitic marble. The dolomite is typically thin bedded to laminated; in some places the rock is massive to thick bedded and displays faintly laminated beds.

Argillite occurs mostly as partings or laminae in dolomite, but in the middle and lower parts of the formation, thin beds of argillite are present in well-defined zones. Most argillite is maroon or gray. Salt casts(?) mark a maroon argillite zone about 50-75 m below the top of the formation (Miller and Whipple, 1989). Nodular chert beds are present at several horizons, but chert is most abundant between the salt cast-bearing argillite and the top of the formation. Siltite is present in these argillite zones in some places, and quartzite is found in the argillite zone in the lower part of the section exposed near the Jim McGraff quarry (sec. 12, T. 31 N., R. 39 E.). Conglomerate consisting of siltite and argillite clasts in a dolomitic matrix is present near the base of the formation in some places. A possible solution breccia is exposed near the Double Eagle quarry (secs. 24 and 25, T. 31 N., R. 38 E.)(Evans, 1987). Algal structures and ooliths can be found in the upper part of the formation; sparse graded beds and ripple marks occur throughout the formation.

From T. 32 N. southward the upper contact with the overlying Buffalo Hump Formation (Yar$_b$, Yq$_b$) is both conformable and unconformable (Campbell and Loofbourow, 1962), but where Miller and Whipple (1989) observed this contact, it was either sheared or faulted. North of T. 32 N. and between Wrights Mountain and Chewelah, the Stensgar Dolomite is unconformably overlain by rocks of the Huckleberry Formation (Zmv$_h$, Zcg$_h$). The lower contact with the underlying McHale Slate (Yar$_m$) is conformable. Miller and Whipple (1989) report a thickness of 200-250 m for the Stensgar Dolomite; Campbell and Loofbourow (1962) suggest thickness ranges between 90 m and 120 m along Huckleberry Mountain. The formation probably thins from east to west.

The Stensgar Dolomite includes irregularly distributed bodies of gray, black, and red magnesite; it is the only formation in the Deer Trail Group to contain magnesite. The contact between dolomite and magnesite is both gradational and abrupt (Campbell and Loofbourow, 1962). Magnesite bodies parallel and cross-cut bedding at high angles, and they are not restricted to any particular part of the formation (Evans, 1987). Magnesite may be sedimentary (or diagenetic) or hydrothermal in origin; regardless of origin, it appears to have been hydrothermally redistributed (F. K. Miller, USGS, written commun., 1990).

Yar$_m$

McHale Slate (Middle Proterozoic)--Well-laminated to indistinctly laminated, mostly phyllitic argillite and minor interbedded siltite and slate. The lowest 100-120 meters of formation consists of medium- to dark-gray argillite with distinct, tan, light-gray, or white laminae (Miller and Whipple, 1989). Bedding ranges from laminae <1 mm thick to fining-upward couplets $\leq$30 mm thick. Along the southwestern flank of Huckleberry Mountain, the upper part of the formation is evenly bedded or laminated, and soft-sediment deformation is rare; along the northeastern flank of the Huckleberry Mountain, wavy bedding or lamination is disrupted by soft-sediment deformation (Miller and Whipple, 1989). The upper two-thirds of the formation consist of green-gray argillite zones alternating with lavender-gray argillite zones (Miller and Whipple, 1989); these zones range from 0.5 m to 30 m in thickness. Bedding and lamination are well developed but indistinct due to lack of color contrast among laminae or beds. In some places the argillite includes light-colored siltite beds 2-20 mm thick; some siltite beds are graded. Metacrysts of ankerite and pyrite altered to limonite characterize at least one horizon of light-gray, fissile slate (Campbell and Loofbourow, 1962); it is not known if this horizon is unique (F. K. Miller, USGS, written commun., 1990). Most rock has a well-developed cleavage that parallels or cuts bedding at high angles.

The McHale Slate is conformably overlain by the Stensgar Dolomite (Ycb_s); in most places the upper 20-30 meters of the unit grade into the overlying dolomite. Along the northeastern part of Huckleberry Mountain the unit is overlain by maroon argillite of the Stensgar Dolomite. The contact with the underlying Edna Dolomite is conformable (Becraft and Weis, 1963; Campbell and Loofbourow, 1962).

Faults and folds preclude accurate measurements of the formation thickness. Campbell and Loofbourow (1962) report the thickness ranges between 300 m and 460 m; Miller and Whipple (1989) estimate the thickness is about 370 m.

Ycb_e

Edna Dolomite (Middle Proterozoic)--Upper half of the formation composed gray and white, tan-weathering dolomite; lower half composed of light-gray to light-green argillite and siltite interbedded with pale-tan dolomitic quartzite and siltite and tan dolomite. Thin interbeds and laminae of argillite are abundant. Most dolomite in the upper half of the formation is fine grained, but some is recrystallized or silicified. The dolomite is typically ferruginous and calcareous and contains secondary quartz veins and pods and minor chert. Bedding is even to wavy and averages 10 cm thick; many thinner beds are contorted. Stromatolitic structures are preserved where the rock is not sheared. The upper and middle parts of the formation are marked by distinct zones of thick- to thin-bedded, white and gray, vitreous quartzite. In the lower half of the formation abundant beds of tan dolomite are characteristically pyrite-bearing and weather to a deep-orange-red soil. The lower part of the Edna Dolomite strongly resembles the carbonate-bearing rocks found directly below the uppermost quartzite of the underlying Togo Formation (Yq_t) (Miller and Whipple, 1989). The dolomite is poorly exposed, and in many places it was mapped on the basis of the presence of orange-red soil.

The Edna Dolomite conformably overlies the upper quartzite of the Togo Formation (Yq_t). Campbell and Loofbourow (1962) estimate the Edna Dolomite ranges in thickness between 460 m and 760 m; Miller and Whipple (1989) report the average thickness is about 410 m.

Yq_t, Yar_t

Togo Formation (Middle Proterozoic)--The Togo Formation is composed chiefly of argillite and as many as four discrete zones of quartzite. The base of the Togo Formation not exposed. The formation is faulted and folded internally. Miller and Whipple (1989) estimate a maximum, composite thickness of at least 650 m; Campbell and Loofbourow (1962) estimate the formation is about 1,200 m thick along the southwestern flank of Huckleberry Mountain; Becraft and Weis (1963) estimate the formation is about 6,000 m thick southwest of the map area.

Yq_t

Quartzite--Mostly quartzite, lesser amounts of siltite and argillite, and minor dolomitic quartzite. A distinct zone of quartzite lies at the top of the Togo Formation, and as many as three other discrete zones of quartzite are present in the upper half of the formation. The uppermost quartzite zone consists of medium- to fine-grained, vitreous quartzite with wavy to even bedding and lamination; many even beds are cross-bedded, and most wavy beds are disrupted by soft-sediment deformation and compaction features. Syneresis cracks and fluid escape structures are abundant in a few places. Distinctive interbeds of siliceous siltite with alternating light and dark laminae are common. Along the northeastern flank of Huckleberry Mountain, the uppermost quartzite includes many gray argillite interbeds ranging in thickness from <1 mm to 2 m. Argillite interbeds decrease in abundance southwestward; southwesternmost exposures contain almost no argillite. Quartzite in the uppermost zone is composed mostly of quartz except in a transitional zone with the underlying argillite (Yar_t); the 5-10-m-thick transitional zone consists of a bed-by-bed gradation from quartzite to argillite. The uppermost quartzite zone averages about 150 m thick and thickens to the southwest (Miller and Whipple, 1989; Miller and Clark, 1975; Campbell and Loofbourow, 1962). The other three discrete zones of quartzite found in this formation range from almost pure quartzite to silty quartzite that has interbeds of quartzitic siltite and argillite; most quartzite beds are capped by argillite. These lower three quartzite zones include minor fine- to medium-grained, dolomitic quartzite.

Yar_t

Argillite--Mostly light- and dark-gray, silvery-gray, black, or green argillite and some gray, black, and green siltite. The argillite includes a few distinct zones of carbonate-bearing clastic rocks and dolomite. In some places green argillite and gray or green siltite are present in distinct zones or beds. Bedding in the argillite ranges from laminae <1 mm thick to as much as 10 cm thick. Thicker beds are typically evenly bedded; thinner beds are disrupted by soft-sediment deformation. Laminated rock typically consists of white to light-gray siltite or argillite laminae separating dark argillite laminae. Most light-colored siltite beds weather orange. The argillite is typically composed of muscovite, angular quartz, feldspar, and abundant disseminated pyrite. Within 60 m of an intrusive body, the argillaceous rocks are phyllitic, slatey, or hornfelsed. Siltite beds range from 1 mm to 4 cm thick; some beds are cross-bedded or graded.

A distinctive zone of carbonate-bearing rocks, similar to strata in the lower half of the Edna Dolomite (Ycb_e), lies below rocks of the uppermost quartzite zone (Yq_t) (Miller and Whipple, 1989). This zone consists of about 200 m of tan dolomite, tan carbonate-cemented quartzite, and pale-green argillite; all carbonate-bearing rocks in this zone weather orange-red. Most dolomite beds contain pyrite. Bedding in the carbonate-bearing zone is typically wavy and ranges from 1 cm to 10 cm thick. Near contacts with intrusive bodies the carbonate-bearing rocks grade into calc-silicate hornfels.

Yar_{dt}

Deer Trail Group, undivided (Middle Proterozoic)--Gray, black, and olive-green, laminated to thin-bedded argillite and thin-bedded siltite. The unit is restricted to areas west of Jumpoff Joe Lake and northwest of Deer Mountain in the Iron Mountains. West of Jumpoff Joe Lake the unit resembles parts of both the McHale Slate (Yar_m) and the Togo Formation (Yar_t) (Miller and Clark, 1975). The lower contact is the trace of the Jumpoff Joe fault. Northwest of Deer Mountain the unit consists of about 200-300 m of strata probably belonging to the Stensgar Dolomite (Ycb_s) and the McHale Slate (Yar_m) (Lindsey, 1988; Miller and Yates, 1976). There, the unit is unconformably overlain by the greenstone member of the Huckleberry Formation (Zmv_h), and the lower contact is the trace of a low-angle reverse fault probably associated with the Jumpoff Joe fault (F. K. Miller, USGS, oral commun., 1989).

Belt Supergroup

The Middle Proterozoic Belt Supergroup is a sequence of siltite, argillite, quartzite, and minor impure dolomite and carbonate-bearing clastic rock. In the map area, the Belt Supergroup consists of, in decreasing order, the Missoula Group, the Wallace Formation, the Ravalli Group, and the Prichard Formation. The Striped Peak Formation is the only formation representing the Missoula Group in the map area.

Yms_d, Yms_c, Yms_b, Yms_a, Yms_{sp}

Missoula Group, Striped Peak Formation (Precambrian Y)--The Striped Peak Formation has been divided into four informal members consisting of siltite, argillite, dolomite, and quartzite.

The four informal units in the map area are correlative with the four informal members of the Striped Peak Formation as mapped east of Pend Oreille Lake in the Clark Fork quadrangle by Harrison and Jobin (1963) (Fig. 5); letter designations (a, b, c, d) are given to the four informal members in the map area, following the usage of Miller and Clark (1975) and Miller and Whipple (1989). In the map area the formation is present in the upper plate of the Newport fault (Miller, 1974a, 1974b) on either side of the Pend Oreille River and in the lower plate of the Newport fault in a belt extending from Eagle Mountain southward to Jumpoff Joe Mountain (Miller and Clark, 1975). For this report, the Striped Peak Formation in the upper plate is informally referred to as the Newport section, and the formation in the lower plate as the Chewelah section.

Yms_d

Member d--Siltite, argillite, and quartzite characterized by deep hematite-red or maroon coloration. In the Newport section, member d consists of coarse-grained siltite and abundant thin argillite interbeds and thicker, fine-grained quartzite interbeds; detrital muscovite is characteristic. Much of the quartzitic siltite and quartzite is feldspathic and has a porous appearance. Most bedding is even and ranges from <1 cm to about 1 m thick. Cross-bedding, cross-lamination, and mud-chip breccia are common; ripple marks are sparse. The member is about 170 m thick in the Newport section (Miller and Whipple, 1989).

In the Chewelah section, the maroon siltite of member d contains thin interbeds of argillite and quartzite; argillite is also present as partings along bedding planes. Bedding averages about 2 cm thick; some beds are indistinctly laminated, and in some places the beds are cross-laminated and graded. Well-developed ripple marks, mud cracks, and salt casts are abundant. Member d has a maximum thickness of about 200 m in the Chewelah section (Miller and Clark, 1975); however, in the Chewelah section north of Cottonwood Creek, member d is absent due to erosion prior to deposition of the Addy Quartzite.

In both sections, a basal zone of green-tinted rock makes up the lowermost part of the member. In the Newport section, the green zone consists of about 10 m of gray-green quartzite, quartzitic siltite, and argillite. Transition from this basal zone into the overlying maroon rock takes place over about 2 m. In the Chewelah section, the green zone consists of only 0.6 m of green siltitic quartzite.

Member d is unconformably overlain by the Lower Cambrian-Upper Proterozoic Addy Quartzite ($\text{€}Zq_a$). Rocks of the green zone conformably overlie the laminated argillite of member c (Yms_c).

Yms_c

Member c--Gray, laminated argillite, lighter colored, fine-grained siltite, and siltitic quartzite. About 70 meters of medium- to dark-gray, evenly laminated argillite make up most of the member in the Newport section. Thin to microscopic laminae consist of light-gray argillite and siltite. Sedimentary structures are rare, except for subtly graded and finely cross-laminated beds. Argillite has a weakly developed bedding-plane cleavage, causing it to weather into thin, flaggy fragments. Thin interbeds of pale green-gray siltite are present in the upper part of the member and mark the transition into the overlying member d (Yms_d); the upper contact of member c is placed at the top of the uppermost gray laminated argillite bed in the transition zone.

In the Chewelah section, member c is composed of well-laminated argillite that has interbeds (<2.5 cm thick) of siltite. Most laminated argillite is medium to dark gray, but some is black or black and white; most siltite is light-gray. Zones of laminated argillite separate thicker zones containing interbedded siltite. The upper part of the member consists of about 15-30 m of olive-green, finely laminated argillite underlain by about 60 m of interbedded dark argillite and siltitic quartzite. Detrital mica is most abundant in the upper 60 m of the member.

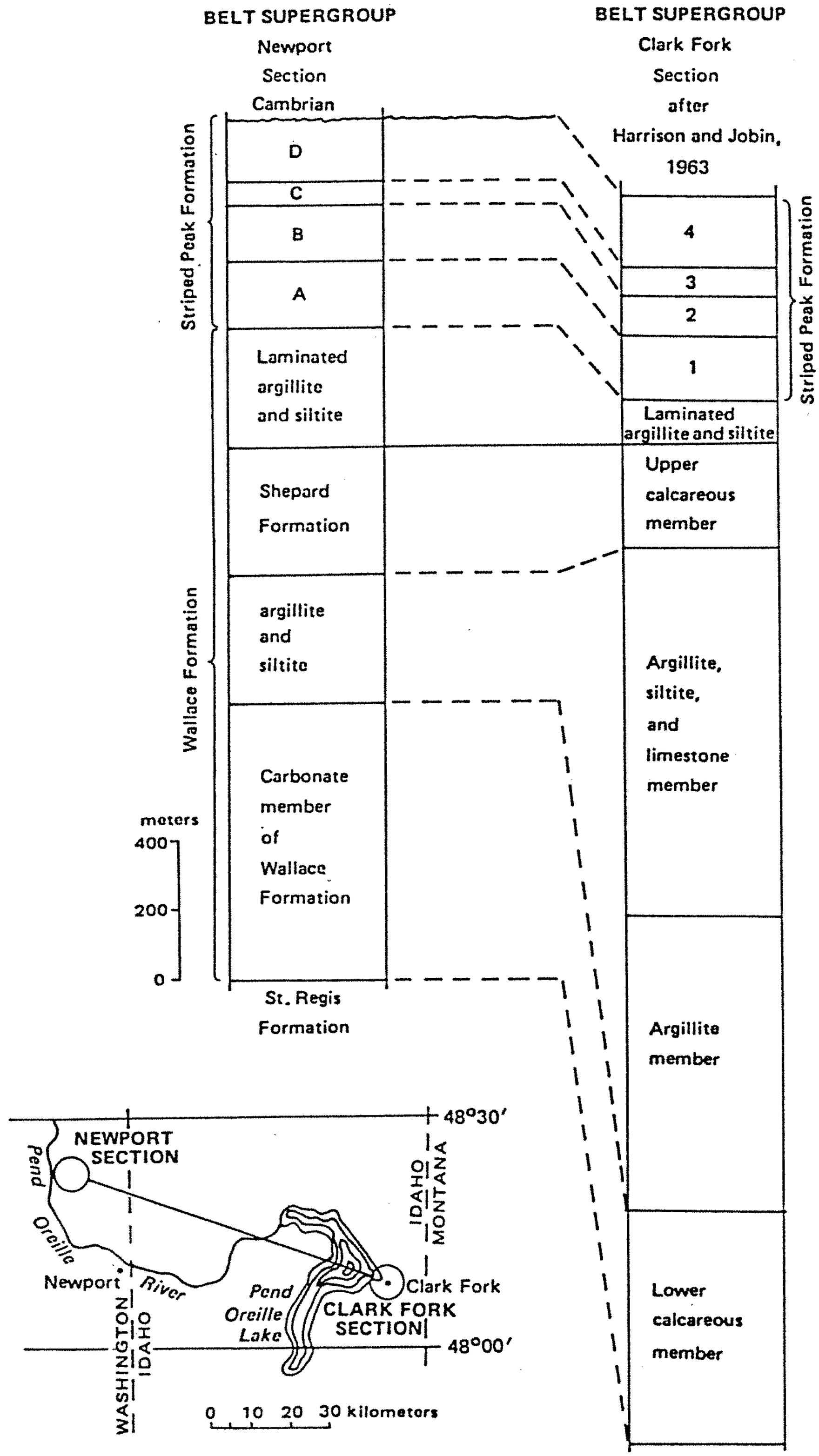


Figure 5. Stratigraphic correlation between the Newport section and the Clark Fork section of the Striped Peak Formation and the Wallace Formation (after Miller and Whipple, 1989, fig. 4).

Near the middle of the member, a zone (about 100 m thick) of nonlaminated, green- and yellow-tinted, light-gray siltite and siltitic quartzite is present; bedding ranges from about 5 cm to about 15 cm thick in this zone. A zone of pale-gray-green, laminated argillite and siltite, characterized by thin seams or lenses of pink, coarser grained siltite lies above the green- and yellow-tinted rock. A zone about 20 m thick of purple-tinted quartzitic siltite interbedded with black, laminated argillite is found below the green- and yellow-tinted rock. The transition into rocks of the overlying member d (Yms_d) is marked by a zone consisting of intervals of maroon siltite separated by thicker intervals of dark-gray siltite and laminated argillite. The transition zone overlies the olive-gray argillite. The upper contact is placed at the base of the lowest interval of maroon siltite more than 1 m thick. South of Cottonwood Creek, the lower part of member c was removed by faulting. Miller and Clark (1975) estimate a minimum composite thickness of between 730 m and 880 m for member c in the Chewelah section.

Yms_b

Member b--Tan and gray, impure dolomite that is hematite-stained on weathered surfaces and forms orange-red to deep-red soil. Most dolomite contains several percent sand, silt, and argillaceous material. Stromatolites are present in both the Newport and Chewelah sections and are accentuated by films or laminae of silica. In the 160-m-thick Newport section, some dolomite is white on fresh surfaces and light gray on weathered surfaces. The characteristic gray weathering of this dolomite, along with the gray weathering of some dolomite in the Stensgar Dolomite (Ycb_s), is unique among Middle Proterozoic carbonate rocks in the region (Miller and Whipple, 1989). Bedding thicknesses range from more than 1 m to laminae. Gray and white chert is present as nodules and irregular lenses $\leq$0.5 m in length. Several meters of massive, sedimentary dolomite-chert breccia are present in the lower part of the member. Member b is transitional into overlying member c (Yms_c). The uppermost 20 m of member b includes thin interbeds of slightly phyllitic, gray argillite; the upper contact is placed at the top of the highest dolomite bed.

In the Chewelah section, member b is composed of medium- to thick-bedded dolomite that has abundant argillite partings; closely spaced laminae of silica are found in some thick beds. Gray and tan coloration dominates the lower part, and maroon coloration dominates the upper part. The uppermost part of the member consists of maroon dolomite and carbonate-bearing siltite and zones of thin-bedded, pale-green, carbonate-bearing siltite and gray dolomite. The upper contact is commonly a fault, but in some places the maroon dolomite grades upward into the overlying gray argillite of member c (Yms_c) through a zone of purple argillite; in other places light-gray dolomite separates the zone of purple argillite from the maroon dolomite. The lower contact is everywhere a fault. Miller and Clark (1975) estimated a composite thickness of about 300 m.

Yms_a

Member a--Chiefly siltite. In the Newport section, the member is about 180 m thick and is composed mostly of siltite and lesser amounts of argillite, quartzite, and dolomite. The upper and middle parts are dominantly gray-green, carbonate-bearing, coarse-grained siltite and fine-grained quartzite. Bedding in the siltite averages 2.5 cm thick. Bedding is wavy to even; graded couplets are common, and cross-laminations are locally present. Salt casts, mud-chip breccia, mud cracks, fluid escape structures, and ripple marks are found throughout the member. Dolomite interbeds range from about 5 cm to more than 1 m thick. Some dolomite interbeds are stromatolitic. Dolomite interbeds are thickest and most abundant in upper 50 m of the member, where the dolomitic zone grades into the overlying dolomite of member b (Yms_b). The lower part consists of carbonate-bearing, pale-green, tan-weathering siltite and argillite. Several interlayers, less than 1 m thick, of dark-gray, laminated argillite in the lowermost 50 m mark the transition into laminated argillite of the underlying upper unit of the Wallace Formation (Yms_{wu}).

In the Chewelah section, member a consists of medium-gray to olive-gray siltite that has partings or thin interbeds (<2.5 cm) of dark-gray to black argillite. Some siltite beds have a green or pink tint. Most siltite is thin to medium bedded, and on weathered surfaces, some beds show internal lamination. Detrital mica is abundant in both siltite and argillite. The uppermost part of the member consists of about 30 m of thinly laminated, deep-red or maroon siltite and argillite; many thin lenses of fine-grained quartzite are present in the upper part. Several 3-m-thick layers of flaggy, light-gray- to lavender-weathering siltite lie near the top of member. Mud-chip breccia, mud cracks, and ripple marks are abundant. Member a in this quadrangle lacks the coloration (reds, pinks, and greens), salt casts, and carbonate-bearing rocks characteristic of the member east of the map area. In most places, the upper contact is a fault, but near Loon Lake member a unconformably underlies the Addy Quartzite (€Zq_a). The lower contact is transitional into the upper unit of Wallace Formation (Yms_{wu}) through a zone about 15-30 m thick. The thickest preserved section is about 300 m thick (Miller and Clark, 1975).

Yms_{sp}

Striped Peak Formation, undivided--Siltite, argillite, and quartzite and some dolomite and dolomitic rock. Most siltite and quartzite are medium gray, and most argillite is dark gray but has a pink tint. Bedding ranges from about 1.5 m thick to thin laminae. Even though recrystallization has destroyed many of the primary features, mud cracks, mud-chip breccias, cross-lamination, and ripple marks are preserved in some places. The formation is mapped as undivided at the north edge of the map area west of the Pend Oreille River (Miller, 1974b) because exposure is incomplete and the rocks are extensively thermally metamorphosed (F. K. Miller, USGS, written commun., 1990). The poorly exposed section has an apparent thickness of about 300 m. Both upper and lower contacts are covered, but the upper contact with the Addy Quartzite (€Zq_a) is probably unconformable, and the lower contact with the Wallace Formation (Yms_{wu}) is probably gradational.

Yms_{wu}, Yms_{wl}, Yms_w

Wallace Formation (Middle Proterozoic)--Argillite, siltite, quartzite, and impure dolomite. For this report the Wallace Formation in the upper plate of the Newport fault is informally referred to as the Newport section and in the lower plate, as the Chewelah section. In the Newport section east of the Pend Oreille River, the formation is undivided, but in the Newport section west of the Pend Oreille River and in the Chewelah section, the formation is divided into an upper and lower unit. The upper unit is dominated by argillite, and the lower unit by carbonate-bearing quartzite and siltite interbedded with laminated argillite. The lower unit is characterized by uneven bedding (pinch-and-swell), syneresis cracks, ripple marks, mud cracks, and cross-lamination.

Miller and Whipple (1989) tentatively assigned strata of the Wallace Formation, previously undivided in the Newport section east of the Pend Oreille River, to four informal units (Fig. 6). Because mapping incorporating this tentative lithostratigraphic division is not available, the Newport section east of the Pend Oreille River is shown on Plate I as it was originally mapped by Miller (1974a, 1974b). The lithostratigraphy of the Wallace Formation in the Chewelah section must be revised (Miller and Whipple, 1989).

On the basis of lithostratigraphy, Miller and Whipple (1989) tentatively correlated part of the Wallace Formation and the Striped Peak Formation (Missoula Group) in the Newport section to part of the Deer Trail Group on Huckleberry Mountain (Fig. 6). The upper part of the Edna Dolomite and the McHale Slate are close lithologic correlatives of the Shepard Formation and the laminated argillite and siltite unit, respectively, of the Wallace Formation; the Stensgar Dolomite correlates well with members a and b of the Striped Peak Formation. Lithologic correlation of strata above and below the strongly correlative units remains obscure; however, members c and d of the Striped Peak Formation may be correlative with the lower part of the Buffalo Hump Formation.

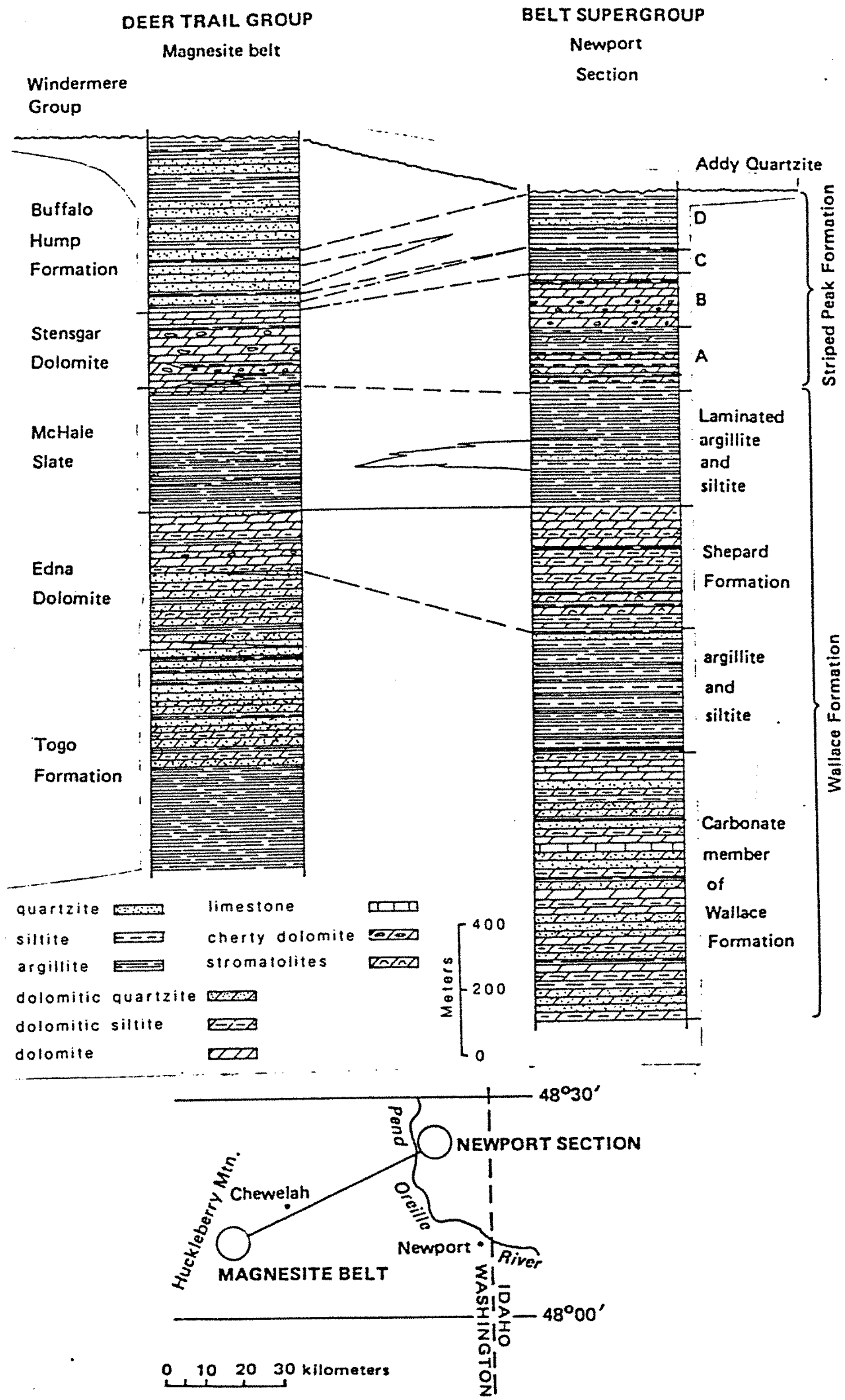


Figure 6. Stratigraphic correlation between the Newport sections of the Striped Peak Formation and the Wallace Formation and the Deer Trail Group (after Miller and Whipple, 1989, fig. 4).

Yms_{wu}

Upper unit--Dark-gray to black, laminated argillite that contains zones of fairly pure tan dolomite. Carbonate-bearing quartzite, siltite, and argillite are subordinate constituents. Quartzite and siltite are unevenly bedded, and argillite is finely laminated. Mud cracks, ripple marks, cross-lamination, and clastic dikelets are present throughout the unit. Near intrusive bodies the argillitic rocks grade into andalusite-cordierite-mica-quartz-oligoclase hornfels and schist, and dolomite grades into coarsely recrystallized dolomitic marble.

In the Chewelah section, the upper contact is a fault or the unit unconformably underlies the Addy Quartzite (€Zq_a); in the Newport section west of the Pend Oreille River, the upper contact is gradational into the overlying Striped Peak Formation (Yms_{sp}, Yms_a) through a zone of about 15-30 m thick (Miller, 1974b; Miller and Clark, 1975). East of Chewelah, the unit is 760-900 m thick (Miller and Clark, 1975).

Yms_{wl}

Lower unit--Pale-tan quartzite, siltite, carbonate-bearing quartzite and siltite, and impure carbonate rock alternating with beds of dark-gray to black, finely laminated argillite. Even though the lower unit has varied lithologies, it is easily recognized by the characteristic pinch-and-swell of beds, which are best developed in coarser grained, carbonate-bearing rocks. Most quartzite and siltite beds grade upward into argillite. Laminae in the argillite are typically disrupted by syneresis cracks, mud cracks, ripple marks, and cross-lamination. Near intrusive bodies the rocks grade into calc-silicate hornfels, metaquartzite, and schist interbedded with phyllite.

The contact with the overlying upper unit is gradational through a zone about 45-60 m thick. Carbonate content and grain size in the lower unit decrease upward. In the Newport section, at the north edge of the map area, the lower unit is about 550 m thick (Miller, 1974b). In the Chewelah section, just north of Deer Lake, the lower unit is about 1,100 m thick (Miller, 1969, 1974c). The contact with underlying St. Regis Formation (Yms_s) is gradational through a zone about 30 m thick. The contact is placed at the base of horizon where carbonate-bearing, light-colored quartzite and dark-colored argillite are more abundant than the green argillite of the upper part of the St. Regis Formation; carbonate-bearing beds are present above and below this basal contact.

Yms_w

Wallace Formation, undivided--Quartzite, siltite, argillite, carbonate-bearing quartzite and siltite, and impure dolomite. Tan and light-gray quartzite and siltite are irregularly interbedded with dark-gray, laminated, slightly phyllitic argillite. The lower part of this unit is dolomite-rich, and the upper part is argillite-rich. Sedimentary features, typical of the lower unit of the Wallace Formation (Yms_{wl}), are abundant in the lower part of the undivided unit. Internal faulting precludes accurate determination of the thickness; the thickest partial section is about 1,300 m thick (Miller, 1974a).

Yms_{bu}

Belt Supergroup, upper part, undivided (Middle Proterozoic)--Light-gray, laminated argillite and tan siltite restricted to the areas northwest of Fan Lake (Miller, 1974c). Intense alteration and bleaching have destroyed primary features needed to assign the rocks to a specific formation. The stratigraphic position of the unit above the lower unit of the Wallace Formation (Yms_{wl}) suggests that the argillite and siltite may belong to the upper unit of the Wallace Formation (Yms_{wu}) and some rock may belong to the lower part of the Striped Peak Formation (Yms_{sp}). The unit has a maximum thickness of about 1,400 m. The upper contact is everywhere a fault. North and west of Fan Lake, the lower contact with the lower unit of the Wallace Formation (Yms_{wl}) is placed about 900 m above the base of the Wallace Formation (Miller, 1974c).

Ravalli Group

The Ravalli Group in the map area consists of three formations: the St. Regis, the Revett, and the Burke.

Yms_{sr}

St. Regis Formation (Middle Proterozoic)--Interbedded siltite and argillite and subordinate quartzite. The formation is characterized by maroon-tinted strata overlain by a distinctive zone of green-tinted strata. Finer grained rocks are more deeply pigmented. In some places the rocks are bleached. The upper part of the formation consists of carbonate-bearing and carbonate-free, yellow-green to light-green siliceous argillite; in some places green-tinted siltite is present. Most rocks in the upper part of the formation are thinly bedded to laminated; bedding is uneven in the uppermost part of the formation. Mud-chip breccia, mud cracks, ripple marks, and cross-lamination are abundant, especially near top of the formation. The green-tinted rocks of the upper part of the formation grade downward into maroon-tinted rocks. The middle and lower parts of the formation consist of maroon to lavender interbedded siltite and argillite; lavender quartzite beds are abundant at some horizons of the maroon-tinted sequence. Bedding ranges from thin laminations to about 1 m thick but averages about 5 cm thick. Siltite and quartzite form thicker beds, and most are capped by argillite partings.

The upper green-tinted sequence grades, bed-by-bed, through a zone about 30 m thick into rocks of the overlying Wallace Formation (Yms_{wl}). The St. Regis Formation grades downward, through a transitional zone about 15-30 m thick, into quartzite of the Revett Formation (Yms_r). The lower contact is placed at the base of the horizon where siltite and argillite are more abundant than quartzite (Miller, 1974c; Miller and Clark, 1975). The St. Regis Formation is about 300 m thick in the Newport section and about 500 m thick in the Chewelah section.

Yms_r

Revett Formation (Middle Proterozoic)--White to light-gray, fine-grained, vitreous quartzite with lesser siltite and sparse argillite. Finely disseminated opaque minerals are moderately abundant; in some parts of the formation, opaque minerals constitute heavy-mineral bands. Much of the rock contains spherical vugs, giving weathered surfaces a pock-marked appearance. Quartzite is moderately to well sorted and well bedded; beds average 0.45 m thick. Siltite beds are most abundant in the transitional zones at upper and lower contacts and in a 30- to 150-m-thick zone near the middle of the formation. Argillite is present throughout the formation as thin beds and partings. Sedimentary features such as ripple marks, mud cracks, and cross-bedding are ubiquitous.

The upper contact is gradational. The uppermost 30-60 meters of formation typically consist of white and lavender quartzite that grades upward into maroon siltite and argillite of the St. Regis Formation. However, in the Newport section, the quartzite of the upper Revett Formation is pink or maroon (Yms_{sr}) (Miller, 1974c; Miller and Clark, 1975). The contact with the underlying Burke Formation (Yms_{bf}) is gradational through a zone 60-120 m thick (Miller and Clark, 1975); the lower contact placed at the base of the horizon where vitreous quartzite is more abundant than siltite. Because the upper and lower contacts are gradational through wide zones, the contacts are difficult to place consistently, and thus the reported thickness of the Revett Formation is varied. The Revett Formation ranges from about 700 to 790 m thick in the Newport section (Miller, 1974a, 1974b) and averages about 900 m in the Chewelah section (Miller, 1974c; Miller and Clark, 1975).

Yms_{bf}

Burke Formation (Middle Proterozoic)--Well-bedded, gray siltite and subordinate fine-grained quartzite and argillite. Quartzite is more abundant in the upper part of formation. Siltite characteristically weathers a lighter gray than fresh rock. A distinctive zone of red, maroon, pink, and lavender siltite, argillite, and quartzite, about 60 m thick, near the middle of the formation resembles the younger St. Regis Formation (Yms_s). Most beds range from 15 cm to 30 cm thick, but some beds are as much as 3 m thick; finer grained rocks form thinner beds, and coarser grained rocks make up the thicker beds. Cross-lamination and ripple marks are more abundant in finer grained strata. Near intrusive bodies, the formation consists of muscovite-biotite-plagioclase-quartz hornfels and schist in which sedimentary features, except bedding, are obscured.

The reported thickness of the Burke Formation depends on placement of the upper and lower contacts. The upper contact with the overlying Revett Formation (Yms_r) is difficult to place because it is gradational over a wide zone. For this report, it is placed at the top of the horizon at which siltite exceeds vitreous quartzite. The contact with underlying Prichard Formation (Yms_p) gradational over a zone about 45 m thick; the transition zone consists of alternating beds of argillite and siltite. In the Newport section, Miller (1974a) includes this transition zone in the Prichard Formation, and thus the thickness of the Burke Formation ranges between about 640 m and about 940 m. In the Chewelah section, Miller and Clark (1975) include the transition zone in the Burke Formation, and therefore thickness ranges between about 900 m and about 1,100 m (Miller and Clark, 1975).

Yms_p

Prichard Formation (Middle Proterozoic)--Argillite, siltite, and quartzite. Thin layers and disseminated grains of pyrite and/or pyrrhotite are present in most fine-grained rocks, resulting in the rusty weathering characteristic of the formation. Quartzite is only slightly less abundant than argillite and siltite; most quartzite is well sorted and is present as sharply bounded beds and zones. Most argillite is laminated, most siltite is thin bedded, and most quartzite is thick bedded. Faint cross-laminations and subtly graded beds are found throughout the formation, but mud cracks and ripple marks are most abundant in the uppermost part. Metadiorite and metagabbro sills are intercalated with the metasedimentary rocks in the lower and middle parts of the formation.

In the Newport section, the formation consists of an upper part, about 600-900 m thick, of dark- to light-gray, laminated argillite; interbedded quartzite is present in the uppermost 150-300 m. The argillite is underlain by about 2,100 m of interbedded siltite, quartzite, and argillite, which are, in turn, underlain by about 600 to 900 m interbedded quartzite and siltite and sparse argillite (Miller, 1974a). The lower 1,200-1,800 meters (F. K. Miller, USGS, written commun., 1990) of the formation consist of mostly hornfelsed siltite, quartzite, and argillite. In the Newport section the transition zone to the overlying Burke Formation (Yms_{bf}) is included in the Prichard Formation and thus, the uppermost 60 meters of the formation contain abundant siltite interbeds. The Prichard Formation is about 5,200 m thick in the Newport section. The base of the formation is not exposed because it is truncated by plutonic rocks.

In the Chewelah section, the Prichard Formation consists of dark-gray to black argillite that has minor siltite in the upper part. Interbedded white to light-gray siltite and gray to white, fine-grained, vitreous quartzite ($\leq$50%) and sparse zones of light-colored argillite constitute the middle part, and interbedded siltite and argillite make up the lower part (Miller and Clark, 1975). The lower part is poorly exposed east of the divide separating the Colville River valley and the Pend Oreille valley. In the Chewelah section, the Prichard Formation is about 4,000 m thick. The upper part is about 1,300 m thick, the middle part is about 980 m thick, and the lower part is about 1,600 m (Miller and Clark, 1975). In this section Miller and Clark (1975) included the transition zone between the Prichard Formation and the Burke Formation (Yms_{bf}) in the Burke Formation. The upper contact is placed at the top of highest 180-m-thick argillite zone below the transition zone. The base of the formation is not exposed because it is truncated by plutonic rocks or grades downward, over a zone as much as 1.6 km thick, into heterogeneous metamorphic rocks (p€hm).

Intrusive Rocks

Hypabyssal Rocks

Ei,

Dikes, undivided (Eocene)--Dikes of varied appearance; most dikes are light to dark gray or shades of pink and porphyritic. Phenocrysts of hornblende, biotite, plagioclase, K-feldspar, quartz, and pyroxene are in a fine-grained or aphanitic groundmass composed of varied amounts of plagioclase (average An$_{15}$), K-feldspar, quartz, hornblende, and biotite. Rarely do more than three phenocryst types occur together, and rarely is more than one phenocryst mineral in a dike altered. Hornblende and biotite phenocrysts are present in 90 percent and 80 percent, respectively, of the dikes; where biotite and hornblende phenocrysts occur together, one of the two minerals is altered and only the unaltered mineral is present in the groundmass. Biotite is altered in all dikes cutting the Silver Point Quartz Monzonite (Eia$_s$). Plagioclase phenocrysts (average An$_{34}$) are present in most dikes, and K-feldspar phenocrysts ($\leq$2 cm) are most abundant in dikes cutting the Silver Point Quartz Monzonite. Many dikes are lamprophyres, but three dikes are coarse grained enough for modal analyses and are classified as quartz monzonite (Miller and Clark, 1975).

Most dikes are between 0.6 m and 9 m in width, but most are traceable for only a few meters and thus they are not shown on the map. Dikes large enough to be shown on Plate I are in the Cottonwood Creek, Jay Gould Ridge, and Fan Lake areas. Dikes are not concentrated enough anywhere in the map area to make up a large proportion of the rock; however, dikes are more abundant in and around the Silver Point Quartz Monzonite (Eia$_s$) and the Phillips Lake Granodiorite (Kiat$_p$) and in the Jay Gould Ridge area. Dikes around the Silver Point Quartz Monzonite are probably genetically related to that pluton (Miller and Clark, 1975). Numerous widely scattered dikes are present in lower Belt Supergroup rocks, but dikes are sparse in Deer Trail Group, Windermere Group, and Paleozoic rocks. Dikes show no preferred regional orientation; rather, they were emplaced along local structural and sedimentary features.

These dikes are the youngest intrusive rocks in the map area. Two lamprophyres north of the map area (Colville 1:100,000-scale quadrangle) yielded ages of 51.2 Ma and 53.0 Ma (Yates and Engels, 1968). A dike northeast of Elk yielded K-Ar ages of 48.0 Ma and 48.5 Ma from biotite and hornblende, respectively (no. 16, Table 5). An Eocene age is assigned to the dikes on the basis of these K-Ar ages and the probable genetic association of some dikes with the Eocene Silver Point Quartz Monzonite.

Dacite dikes (Cretaceous)--Pale-brown to olive-gray dacite dikes consisting of plagioclase and quartz phenocrysts in an aphanitic groundmass. Dikes are deeply weathered and form small rounded exposures in the northwest corner of the map area west of Arden. These dikes are 10-50 m wide and as much as 1.5 km long (Snook, 1981). They intruded the Addy Quartzite (CZq$_a$), Metaline Formation (OCcb$_m$), and Ledbetter Slate (Omm$_l$). Dikes are assigned a Cretaceous age because of their compositional similarities to Cretaceous plutons in the area.

Rhyolite dikes (Cretaceous ?)--Mostly pink, white, and pale-brown rhyolite and rhyolite porphyry dikes; some dikes may be dacite. Most rhyolite dikes are composed of 10-25 percent plagioclase phenocrysts and lesser amounts of euhedral quartz phenocrysts in a fine-grained to aphanitic, quartzofeldspathic groundmass. These dikes are sparsely distributed in T. 31 N., Rs. 38-39 E., where they intruded only Deer Trail Group rocks. Dikes are assigned a Cretaceous age (Campbell and Loofbourow, 1962), but because they cut only the Middle Proterozoic metasedimentary rocks, they could be older.

Plutonic Rocks

For this report, the plutonic rocks have been grouped according to their distribution in relation to the major structural discontinuities in the map area: plutonic rocks in the upper plate of the Newport fault; plutonic rocks in the lower plate of the Newport fault; and plutonic rocks west of the Jumpoff Joe fault. The plutonic rocks can also be grouped mineralogically into two-mica (muscovite-biotite) rocks, hornblende-biotite rocks, biotite-only rocks, and alaskitic rocks. Figure 7 shows the distribution of intrusive rocks in the map area.

Plutonic Rocks in the Upper Plate of the Newport Fault

Kia_g

Galena Point Granodiorite (Cretaceous)--Porphyritic biotite granodiorite to monzogranite that consists of K-feldspar phenocrysts (1-6 cm long) surrounded by a medium- to coarse-grained groundmass composed of quartz, K-feldspar, zoned sodic plagioclase, and biotite (12% average) (Miller, 1974a); accessory minerals include zircon, apatite, allanite, and opaque minerals. Some muscovite is visible in thin section. In parts of the pluton, the rock contains sparse hornblende and sphene. Discontinuous zones of finer grained, nonporphyritic rock are present near the margins of the pluton. Contacts are irregular; numerous granodiorite dikes intrude host rock. The metamorphic aureole extends as much as 1.6 km into the country rock. The pluton is Cretaceous based on a K-Ar biotite age of 101 Ma (no. 16, Table 5).

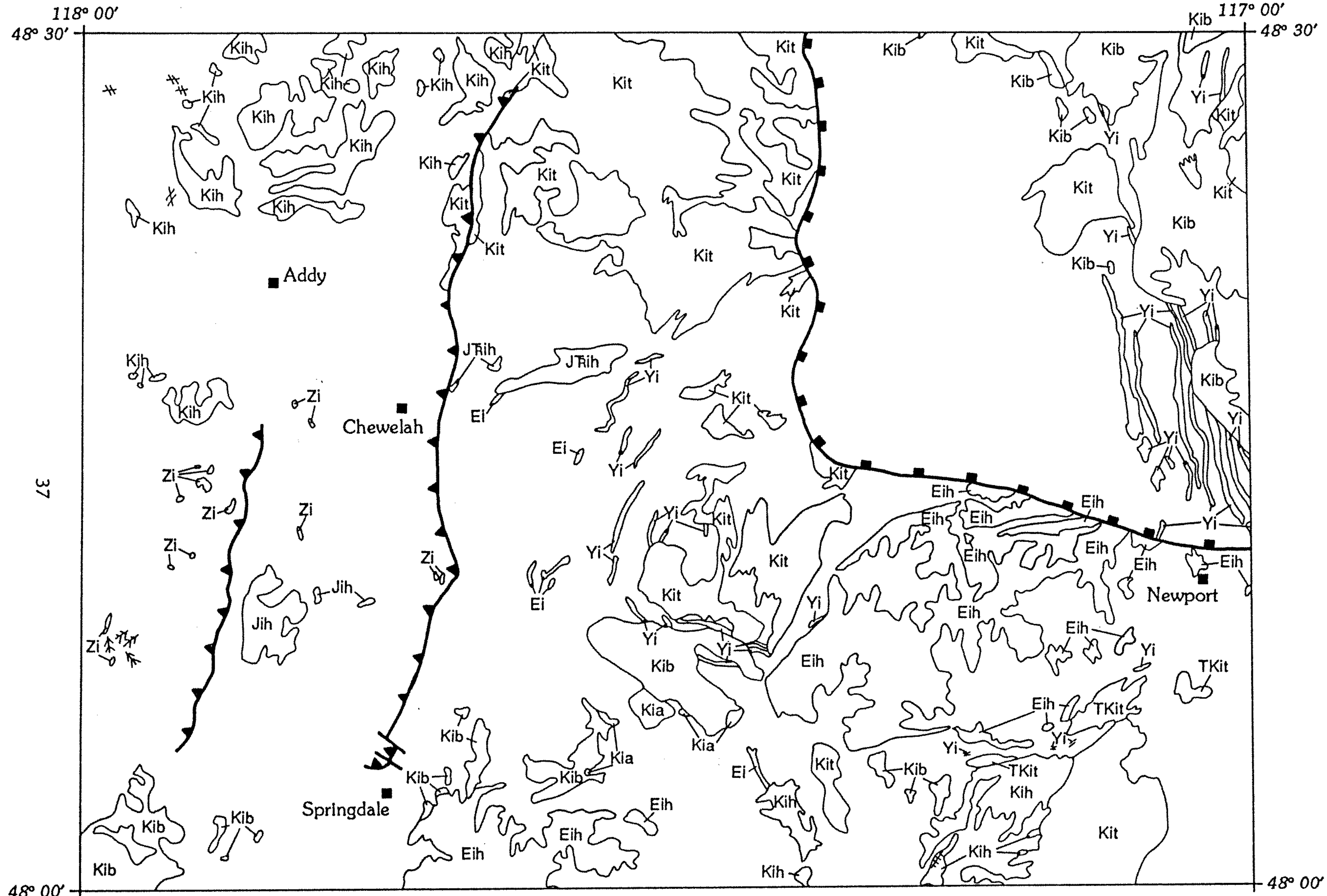
$Kiat_g$

Granodiorite of Hall Mountain (Cretaceous)--Medium- to coarse-grained biotite granodiorite that contains sparse muscovite. Felsic minerals are surrounded by thin rims of very fine grained feldspar, quartz, and mica, suggesting the rock has been quenched. Quartz veins are ubiquitous, and pyrite is commonly present, regardless of whether the rock is altered.

The pluton was originally mapped as part of the Galena Point granodiorite (Kia_g) (Miller, 1974a) but was later identified as part of the granodiorite of Hall Mountain (F. K. Miller, USGS, written commun., 1988). This pluton and several other noncontiguous plutons exposed north of the map area in the Colville 1:100,000-scale quadrangle constitute the granodiorite of Hall Mountain. Based on a K-Ar biotite age of 99 Ma (Miller, 1983) from rock about 30 km north of the map area, the granodiorite of Hall Mountain is considered Cretaceous.

Explanation for Figure 7 (facing page)

Figure 7. Sketch map showing the distribution of the intrusive rocks in the Chewelah 1:100,000 quadrangle. Ei, Eocene dikes, +++ Eocene dikes, Eih, Eocene hornblende-biotite plutonic rocks, TKit, Tertiary-Cretaceous two-mica plutonic rocks, ≻≻≻ Cretaceous(?) rhyolite dikes, ⁄⁄⁄ Cretaceous dacite dikes, Kih, Cretaceous hornblende-biotite plutonic rocks, Kit, Cretaceous two-mica plutonic rocks, Kib, Cretaceous biotite plutonic rocks, Kia, Cretaceous alaskitic plutonic rocks, Jih, Jurassic hornblende-biotite plutonic rocks, J̄Ri, Jurassic-Triassic hornblende-biotite plutonic rocks, Zi, Upper Proterozoic greenstone dikes, and Yi, Middle Proterozoic metadiorite sills.



CHEWELAH
1:100,000 quadrangle

$Kiat_d$

Granodiorite of Dubious Creek (Cretaceous)--Medium-grained muscovite-biotite monzogranite that contains >1 percent muscovite. K-feldspar is microcline; accessory minerals include allanite, zircon, apatite, and opaque minerals. The rock present in the map area is the monzogranitic western part of the granodiorite of Dubious Creek (Miller, 1982; F. K. Miller, USGS, written commun., 1990). The granodiorite of Dubious Creek may include more than one pluton. The part of the pluton in the map area was originally mapped by Miller (1974a) as part of an unnamed muscovite-biotite quartz monzonite and as part of the Galena Point Granodiorite (Kia_g). Nearly concordant K-Ar ages of 95.6 Ma (biotite) and 102 Ma (muscovite) (Miller and Engels, 1975) from the pluton east of the map area indicate the granodiorite of Dubious Creek is Cretaceous.

$Kiat_{bm}$

Monzogranite of Big Meadows (Cretaceous)--Texturally and mineralogically heterogeneous muscovite-biotite monzogranite. Most of the rock is nonporphyritic, and grain size ranges from medium to fine. The unit is composed of biotite (6-8%), muscovite (1-2%), microcline, quartz, and plagioclase (An_{20}); accessory minerals include zircon, apatite, allanite, and opaque minerals (Miller, 1982). Much of the pluton is indistinctly foliated. Parts of the pluton resemble rock of the Blickensderfer Quartz Monzonite ($Kiat_b$). The rock was originally mapped as part of an unnamed muscovite-biotite quartz monzonite (Miller, 1974a). The pluton is assigned a Cretaceous age because of similarities to other Cretaceous plutons in the area.

$Kiat_b$

Blickensderfer Quartz Monzonite (Cretaceous)--Light-gray to white, coarse-grained muscovite-biotite monzogranite (average modal composition) to granodiorite (Miller, 1974a). Major constituents are quartz, microcline, plagioclase, biotite, and muscovite; accessory minerals include zircon, apatite, and opaque minerals. Both micas are visible in hand specimen. Quartz is present as large, smoky crystals; most plagioclase is zoned. Some rock contains microcline phenocrysts, and in some areas it is finer grained along the margins of the pluton. The metamorphic aureole extends as much as 600 m into the country rock. Concordant K-Ar biotite and muscovite ages indicate the pluton is Cretaceous (no. 18, Table 5).

Plutonic Rocks in the Lower Plate of the Newport Fault

Eia_s

Silver Point Quartz Monzonite (Eocene)--Porphyritic hornblende-biotite monzogranite consisting of euhedral, pink orthoclase phenocrysts (0.6-4 cm long) in a bimodal groundmass. The hornblende to biotite ratio is consistently between 3 to 4 and 1 to 1. Sphene is the most abundant accessory mineral and is typically visible in hand specimen; other accessory minerals include apatite, magnetite, zircon, and allanite. The coarser (0.2-0.5 cm) phase of the groundmass consists of hornblende, biotite, plagioclase (An_{20} average), and K-feldspar; the finer (0.05-0.1 cm) phase consists of all mineral constituents. The average modal composition is Q22:A30:P48, and the rock contains 17 percent mafic minerals (Miller and Clark, 1975); most of pluton is monzogranite, but it includes quartz monzonite, granodiorite, and a mafic border phase of quartz monzodiorite west of Newport. Contact metamorphic effects are not evident beyond 0.7 km from the contact. Two noncontiguous plutons make up the Silver Point Quartz Monzonite in the map area. The pluton west of Newport is cut by the Newport fault at its northern margin. The Silver Point Quartz Monzonite is Eocene on the basis of concordant K-Ar ages from cogenetic biotite and hornblende and Rb-Sr whole-rock isochron ages (nos. 19-23, Table 5).

Eii

Quartz monzodiorite near Springdale (Eocene)--Coarse- and medium-grained, equigranular hornblende-biotite quartz monzodiorite to quartz monzonite forming an elongate pluton 3 km southeast of Springdale. This pluton is mineralogically and texturally homogeneous. The hornblende:biotite ratio is about 1:1. Hornblende occurs as single, euhedral crystals and as clusters of crystals that have pyroxene cores. Both K-feldspar and zoned plagioclase (An_{35-20}) are white. Sphene grains $\leq$0.1 cm long are ubiquitous. The average modal composition of the rock is Q14:A31:P55, and the monzodiorite contains 28 percent mafic minerals (Miller and Clark, 1975). Rounded mafic inclusions and aplite dikes ($\leq$15 cm wide) are present throughout the unit. Minimal contact metamorphic effects are evident in the surrounding country rock. Based on its mineralogy and spacial association, the quartz monzodiorite is probably related to the Silver Point Quartz Monzonite (Eia_s) (Miller and Clark, 1975).

The pluton yielded K-Ar biotite and hornblende ages of 50 Ma and 65 Ma, respectively (no. 24, Table 5); the hornblende age is considered anomalous due to excess Ar from pyroxene cores in hornblende crystals (Engels, in Miller and Clark, 1975). On the basis of the biotite age and the probable association of the pluton with the Silver Point Quartz Monzonite (Eia_s), the quartz monzodiorite is assigned an Eocene age.

Eiqm

Fine-grained quartz monzonite near Loon Lake (Eocene)--Hornblende-biotite quartz monzonite characterized by its salt-and-pepper appearance, fine grain size, and pink K-feldspar. Zoned plagioclase has an average composition of An_{20}. The hornblende:biotite ratio is nearly 1:1. Hornblende contains pyroxene cores and occurs in clots with biotite. Sphene is the most abundant accessory mineral and is typically visible in hand sample. The average modal composition of the quartz monzonite is Q15:A39:P46; the rock contains 18 percent mafic minerals (Miller and Clark, 1975). The deeply weathered, poorly exposed pluton is cut by aplite dikes and dark-green, aphanitic dikes. The contact with the monzogranite of Little Roundtop (Kig_l) dips outward <50°, and dikes of quartz monzonite cut the monzogranite of Little Roundtop. The fine-grained quartz monzonite is probably genetically related to the Silver Point Quartz Monzonite (Eia_s) (Engels, in Miller and Clark, 1975).

The pluton yielded K-Ar biotite ages of 51 Ma and 52 Ma and K-Ar hornblende ages as old as 327 Ma (nos. 25-27, Table 5). The anomalously old hornblende ages are due to excess Ar from pyroxene cores (Engels, in Miller and Clark, 1975). On the basis of the probable genetic association with the Silver Point Quartz Monzonite (Eia_s) and the K-Ar biotite ages, the pluton is considered Eocene in age.

TKiaa

Leucocratic plutonic rocks of the Scotia area (Tertiary? to Cretaceous?)--Mixture of muscovite-biotite quartz monzonite, alaskite, pegmatite, and aplite dikes and sills (Miller, 1974d). All rock types are leucocratic and contain muscovite and sodic plagioclase (An_{0-30}); most rocks contain at least some biotite. Alaskite and quartz monzonite are medium to coarse grained; aplite and pegmatite have textures typical of those rock types. The unit is foliated, and parts of it are sheared and have cataclastic textures. Leucocratic rocks intruded the heterogeneous metamorphic rocks (pChm). Pods of heterogeneous metamorphic rocks ($\leq$60 m long) are present in the leucocratic plutonic rocks, and about 5 km west of Scotia Valley the metamorphic pods may be Newman Lake Gneiss (Kog_n). Because abundant dikes and sills of leucocratic plutonic rocks extend into the heterogeneous metamorphic rocks, the contact between the two units is actually a transition zone.

The ages of the four rock types that comose the unit are unknown. Quartz monzonite is cut by alaskite, pegmatite, and aplite. Some quartz monzonite is similar to the quartz monzonite of the Cretaceous Phillips Lake Granodiorite ($Kiat_p$) and may be similar in age. However, emplacement of the leucocratic rocks may have occurred over a considerable time span and thus at least some rock may be as young as Tertiary (Miller, 1974d).

$Kiat_e$

Monzogranite north of Eloika Lake (Cretaceous)--Homogeneous, leucocratic, medium- to coarse-grained muscovite-biotite monzogranite (Miller, 1974c; F. K. Miller, USGS, written commun., 1990). The rock has a slight foliation defined by crude alignment of micas. Biotite is cut by sparse sillimanite needles. The degree of foliation and the abundance of sillimanite do not increase in any one direction. Some cataclasis is obvious in thin section (Miller, 1974c). All contacts are covered, and the age of the pluton, relative to other units in the area, is unknown. The monzogranite was assigned a Cretaceous age because of its similarities to other Cretaceous plutons in the area.

$Kiat_{ms}$, Kog_{ms}

Granite of Mount Spokane (Cretaceous)--A composite pluton consisting of a main granite phase cut by associated leucocratic rocks. In the southern and eastern parts of the pluton the rocks have been deformed; undeformed granite grades into deformed granite which, in turn, grades into banded gneiss. The granite of Mount Spokane is present on the western flank of the Spokane dome. The Spokane dome is defined by a "...NNE-trending gently antiformal zone of mylonitization...." (Rhodes and others, 1989, p. 165); the axis of the dome is east of the map area in Idaho. Mylonitic deformation in the 4-km-thick zone fades structurally downward (eastward) into the nonmylonitic core of the dome and fades structurally upward (westward) into undeformed granite of Mount Spokane (Rhodes, 1984; Rhodes and Hyndman, 1984). The ages of the mylonitized rocks in the Spokane dome establish the maximum age for mylonitization. The mylonitic zone is shown on Plate I by a diagonal line overprint.

The main granite phase of the pluton was emplaced during the middle to Late Cretaceous as determined by U-Pb and Rb-Sr methods (Armstrong and others, 1987; Bickford and others, 1985). The leucocratic rocks were probably emplaced during the Cretaceous, but some may be as young as Tertiary.

$Kiat_{ms}$

Undeformed granite--Medium- to coarse-grained, porphyritic and nonporphyritic muscovite-biotite granite. The two-mica granite contains K-feldspar phenocrysts $\leq$2.5 cm long in some places. Micas make up 4-12 percent of the rock; the muscovite to biotite ratio ranges from 0.2 to 1 (Miller, 1974d). Part or all of the K-feldspar is microcline, and plagioclase ranges in composition from An_{10} to An_{30}.

The southern part of the undeformed granite of Mount Spokane corresponds to the hypidiomorphic rock unit mapped by Weissenborn and Weis (1976) south of the map area. Rock included in the northwestern part of the unit may be part of a different pluton (F. K. Miller, USGS, written commun., 1990). The contact between the northwestern part of the unit and the granodiorite west of Spring Valley ($Kiat_s$) is gradational.

The undeformed granite is cut by leucocratic alaskite-aplite-pegmatite dikes, pods, and bodies (Rhodes, 1984; Rhodes and Hyndman, 1984; Weissenborn and Weis, 1976). Cross-cutting leucocratic rocks are texturally varied, but most are composed of quartz, K-feldspar, plagioclase, muscovite, and accessory garnet, biotite, apatite, zircon, and monazite. South of the map area alaskitic bodies are mapped as a separate unit; the alaskitic rock makes up as much as 50 percent of the pluton, and cross-cutting pegmatite dikes make up about 25 percent of the alaskitic rock (Weissenborn and Weis, 1976). Even though leucocratic rocks make up part of the pluton in the map area, Miller (1974d) did not map them as a separate unit. Contacts between the leucocratic rocks and the granite are gradational.

Kog_{ms}

Deformed granite and banded gneiss--In southern exposures, distinguished by muscovite megacrysts as much as 2.5 cm across. Deformed granite is increasingly foliated and lineated as the mylonitic zone of the Spokane dome is approached. In the mylonitic zone the granitic rock is so intensely deformed that it is a foliated and lineated banded two-mica-feldspar-quartz gneiss. The gently west-dipping mylonitic foliation is defined by alignment of micas; mylonitic lineation is defined by orientation of sillimanite, streaks of mineral grains, and striations. Lineation lies in the plane of foliation and trends about 70°E, although it may vary by 20° to 30°. Some leucocratic rocks cut the mylonitic foliation (Weissenborn and Weis, 1976). In the southern part of the unit, the moderately deformed granite corresponds to the foliated rock unit of Weissenborn and Weis (1976), and the two-mica-feldspar-quartz gneiss corresponds to the banded gneiss unit of Weissenborn and Weis (1976) (Rhodes and Hyndman, 1984, fig. 2; Rhodes and others, 1989, fig. 2). Rocks in the northernmost part of the unit were included only on the basis of foliation and lineation symbols shown on Miller's map (1974d). The contact with the Newman Lake Gneiss (Kog_n) is gradational; the southern part of the contact cuts across the strike of the mylonitic foliation at an angle of about 40°.

$Kiat_s$

Granodiorite west of Spring Valley (Cretaceous)--Medium- to coarse-grained granodiorite to monzogranite. Biotite constitutes $\leq$10 percent of most rock, and muscovite is sparse (Miller, 1974d). The rock is nonfoliate to slightly foliated. At Lake of the Woods, granodiorite dikes cut the Fan Lake Granodiorite (Kia_f). Because of similarities to other Cretaceous plutons in the area, the granodiorite west of Spring Valley is considered Cretaceous but is younger than the 97.5 Ma Fan Lake Granodiorite.

Kia_f

Fan Lake Granodiorite (Cretaceous)--Medium- to coarse-grained hornblende-biotite granodiorite to monzogranite. Most hornblende is of the same grain size as the surrounding minerals, but scattered hornblende crystals are as much as 1 cm long (Miller, 1974c). The rock is porphyritic where large hornblende crystals are abundant. Hornblende:biotite ratio is nearly 1:1. Plagioclase is zoned and has an average composition of An_{20}. Sphene is abundant and typically visible in hand specimen. The Fan Lake Granodiorite is Cretaceous on the basis of K-Ar ages of 95.7 Ma and 97.5 Ma for cogenetic biotite and hornblende, respectively (no. 29, Table 5).

Kia_c

Monzogranite of the Camden area (Cretaceous)--Medium-grained biotite monzogranite to granodiorite composed of plagioclase, K-feldspar, quartz, abundant biotite, and sparse hornblende; magnetite, zircon, and apatite are the most abundant accessory minerals. The western part of the pluton has a cataclastic texture and is incipiently metamorphosed (Miller, 1974c). The pluton is deeply weathered and poorly exposed. Even though it lacks hornblende, the biotite monzogranite resembles and may be genetically related to the Fan Lake Granodiorite (Kia_f). More than one similar pluton may constitute the monzogranite of the Camden area (Miller, 1974c, 1974d). The age of the pluton relative to other plutons in the area is not known; because of its possible association with the Fan Lake Granodiorite, the pluton is considered Cretaceous in age.

Kig_l

Monzogranite of Little Roundtop (Cretaceous)--Deeply weathered biotite monzogranite characterized by its coarse grain size (average about 1 cm). This monzogranite is typically equigranular. However, some of it is indistinctly porphyritic where phenocrysts of pink K-feldspar are as much as 5 cm long, and some rock is distinctly bimodal. Biotite is the only mafic mineral, and the exterior of most grains is chloritic. Plagioclase (average An_{20}) is indistinctly zoned; most plagioclase is surrounded by rims of K-feldspar, and some is sericitic. Sphene is the most abundant accessory mineral. The rock has an average modal composition of Q33:A31:P35 and contains 7 percent biotite (Miller and Clark, 1975). Many leucocratic, fine-grained quartz monzonite and aplite dikes cut the monzogranite, but inclusions are rare.

Three noncontiguous bodies of monzogranite of Little Roundtop are exposed east, west, and south of Deer Lake. Smaller bodies are exposed near Horseshoe Lake and about 3 km east of Eloika Lake. Near Horseshoe Lake the rock has cataclastic texture; east of Eloika Lake, it is metamorphosed, and sillimanite replaces biotite (Miller, 1974c). The contact with the metasedimentary country rock east of Deer Lake appears to dip outward at 40°-50°; contact metamorphic effects are not evident more than 460 m from the intrusive contact.

Deep weathering and chloritization of biotite preclude K-Ar age determination of the monzogranite. Because of its contact relations and compositional similarities to other Cretaceous plutons in the area, the monzogranite of Little Roundtop is assigned a Cretaceous age. This monzogranite is probably younger than the Cretaceous alaskite bodies (Kiaa) (Miller, 1974c); dikes of the Eocene fine-grained quartz monzonite near Loon Lake (Eiqm) cut the monzogranite (Miller and Clark, 1975).

Kiaa

Alaskite bodies (Cretaceous)--Leucocratic, medium- to coarse-grained muscovite monzogranite distinguished by the near absence of mafic minerals and by the presence of extremely sodic plagioclase (average An_3). This rock is pink or pale yellow-tan, depending on the degree of alteration of the K-feldspar. K-feldspar and sodic plagioclase typically are present in nearly equal amounts. K-feldspar and quartz occur interstitially. Garnet makes up as much as 2 percent of the rock. The only dark minerals present are traces of magnetite, pyrite, and limonite. The rock has an average modal composition of Q29:A35:P36 and contains 6 percent muscovite (Miller and Clark, 1975). Five small, noncontiguous bodies of alaskite crop out in the map area: four of the bodies are linearly aligned between Deer Lake and Horseshoe Lake, and one is about 3 km south of Deer Lake. Alaskite bodies lack both cross-cutting dikes and inclusions; however, the southern margin of largest body is cut by huebnerite-bearing quartz veins, and parts of its contact have undergone greisenization. The metamorphic aureole extends about 15 m into the surrounding country rock.

The alaskite bodies are Cretaceous on the basis of a K-Ar muscovite age of 80 Ma (no. 30, Table 5) and contact relations with the other Cretaceous plutons in the area. The alaskite bodies are older than the monzogranite of Little Roundtop (Kig_l) (Miller, 1974c).

$Kiat_p$

Phillips Lake Granodiorite (Cretaceous)--A composite intrusion consisting mostly of a main phase of mostly medium- to coarse-grained muscovite-biotite granodiorite. Dikes and small bodies of leucocratic, fine- and medium-grained, equigranular quartz monzonite and leucocratic aplite-alaskite-pegmatite dikes intrude the granodioritic main phase. The main phase ranges in composition from granodiorite to granite to tonalite, but the average modal composition is Q33:A13:P54, and 15 percent of the rocks is mafic minerals and muscovite (Miller and Clark, 1975). The granodioritic rock is composed of plagioclase (average An_{22}), K-feldspar, quartz, muscovite, and biotite; muscovite is absent in some rock. The muscovite to biotite ratio is nearly 1 to 3. Some rock contains K-feldspar phenocrysts. Apatite and zircon are the most abundant accessory minerals.

Most aplite-alaskite-pegmatite dikes and bodies are biotite-free or biotite-poor. Many pegmatite dikes contain garnet, tourmaline, and sparse beryl or columbite; where they cut the equigranular quartz monzonite, pegmatite dikes contain intergrown muscovite and biotite. Aplite-alaskite-pegmatite rocks make up <1 percent of the area mapped as Phillips Lake Granodiorite; equigranular quartz monzonite dikes and bodies can constitute as much as one-third of the area. There is a progressive increase in dike abundance from the western part of the pluton eastward (F. K. Miller, USGS, written commun., 1990) and near Calispell Peak, dikes constitute about 50 percent of the Phillips Lake Granodiorite. The hachured overprint on Plate I shows where these leucocratic dikes and bodies are abundant. Most of the pluton is weakly and irregularly foliated; foliation is most pronounced in the central part of the pluton (F. K. Miller, USGS, written commun., 1990). The eastern part of the Phillips Lake Granodiorite is cut by the Newport fault.

The Phillips Lake Granodiorite intruded Precambrian heterogeneous metamorphic rocks (p€hm) and Middle Proterozoic rocks of the Belt Supergroup (Yms_p, Yms_{bf}, Yms_r, Yms_s, Yms_{wl}, Yms_{wu}). The metamorphic aureole extends several kilometers beyond the contact, which dips shallowly. Roof pendants are abundant and typically form resistant topographic highs.

Numerous K-Ar age determinations (nos. 31-36, Table 5) indicate that the Phillips Lake Granodiorite has had a complex cooling history but that the main phase was emplaced about 100 Ma (Miller and Engels, 1975) and thus is Cretaceous. Eocene apparent ages (Table 5) reflect the complex cooling history of this composite granitic intrusion (Harms, 1982; Price and others, 1981).

J₹ii_f

Flowery Trail Granodiorite (Lower Jurassic to Upper Triassic)-- Coarse- and fine-grained equigranular biotite-hornblende quartz monzodiorite characterized by low quartz content, abundant sphene, and hornblende being more abundant than biotite. Zoned plagioclase ranges in composition from An_{22} to An_{35}. The rock has an average modal composition of Q16:A29:P55 and contains 31 percent mafic minerals (Miller and Clark, 1975). The composition ranges from quartz monzodiorite to quartz monzonite; granodiorite is minor. Rock with the highest quartz content is found along the margin of pluton. Patches (as much as 60 m^2) of mafic-rich rock and inclusions are abundant throughout the pluton. Much of the rock along the margin of pluton is foliated. The contact with the surrounding country rock is steeply dipping, and abundant dikes and sills of quartz monzodiorite cut the metasedimentary host rocks. The metamorphic aureole extends into the country rock about 1.6 km from the intrusive contact.

The Flowery Trail Granodiorite was emplaced about 200 Ma (Miller and Engels, 1975). Cogenetic hornblende-biotite pairs yield discordant K-Ar age determinations (nos. 37-39, Table 5); discordance increases from west to east (Table 5).

Plutonic Rocks West of the Jumpoff Joe Fault

Kia_m

Midnite mine pluton (Cretaceous)--Leucocratic granite to quartz monzonite cut by alaskite bodies, aplite dikes, and sparse pegmatite dikes (Castor and others, 1982). The rocks are pink, tan, light yellow-gray, and pale-green. Most granite is porphyritic and contains abundant white or pink K-feldspar phenocrysts and lesser amounts of plagioclase and smoky quartz phenocrysts in a medium- to coarse-grained, equigranular to inequigranular groundmass. Local variation in texture is typical; most rock is finer grained and nonporphyritic near the margins of the pluton. Most plagioclase (average An_{13}) is sericitic. Most biotite is chloritic. Most muscovite is probably secondary (Ludwig and others, 1981); some muscovite-bearing rock is deficient in biotite. The rock has a modal composition of Q30-45:A25-40:P20-35 and contains 3-5 percent biotite and <1 percent accessory apatite, magnetite, sphene, zircon, and muscovite (Becraft and Weis, 1963); rutile, pyrite, epidote, garnet, and allanite are present as sparse accessories (Asmerom and others, 1988). Fine-grained alaskite and alaskite porphyry comprise as much as 10 percent of the pluton. Most of the pluton is deeply weathered and covered with a thick mantle of grus. The Midnite mine pluton is anomalously enriched in uranium and is probably the primary source of uranium in the sediment-hosted uranium deposits southwest of the map area (Coulee Dam 1:100,000-scale quadrangle) (Castor and others, 1982; Fleshman and Dodd, 1982).

The Midnite mine pluton intruded Precambrian strata of the Togo Formation (Yar_t, Yq_t). Contact metamorphic effects extend into the country rock about 60 m from the intrusive contact. Most of the pluton lies in the Coulee Dam 1:100,000-scale quadrangle.

The Midnite mine pluton is Cretaceous on the basis of a K-Ar biotite age of 78.1 Ma (no. 40, Table 5) from rock in the map area and on Pb-alpha, Rb-Sr isochron, fission track, Pb-U age determinations from rock outside the map area (Asmerom and others, 1988; Becraft and Weis, 1963; Ludwig and others, 1981).

Kia_s

Starvation Flat Quartz Monzonite (Cretaceous)--Light-gray, medium- to coarse-grained hornblende-biotite monzogranite. Numerous alaskite-aplite dikes and bodies cut the monzogranite. White, zoned plagioclase ranges in composition from An_{20} to An_{35}. K-feldspar is pink or white, and quartz is both clear and smoky. Quartz and K-feldspar are interstitial to the other minerals. Biotite forms euhedral tablets, and hornblende forms single crystals. Sphene is the most abundant accessory mineral and is visible in hand specimen. Mafic inclusions are found throughout the pluton.

The Starvation Flat Quartz Monzonite is zoned from monzogranite to granodiorite. Rock in the eastern part of the pluton has an average modal composition of Q32:A29:P39 and contains 13 percent mafic minerals (Miller and Clark, 1975); the hornblende to biotite ratio averages about 7 to 10. Near the contact with the greenstone member of the Huckleberry Formation (Zmv_h), the eastern part of the pluton is more mafic and calcic and contains more inclusions. Along its eastern margin the Starvation Flat Quartz Monzonite is cut by equigranular quartz monzonite dikes of the Phillips Lake Granodiorite ($Kiat_p$). The contact with metasedimentary country rock is near vertical, and the metamorphic aureole extends about 460 m from the intrusive contact.

A leucocratic interior phase underlies a 25-km^2 oval area extending northeast and southwest of Arden; this phase has an average modal composition of Q33:A32:P34 and includes 7 percent mafic minerals, a trace of muscovite, and no sphene (Castor and others, 1982). The interior phase contains anomalous uranium; quartz veins, shear zones, and late-stage alaskite bodies also contain anomalous uranium.

A body of pink to light-gray, fine-grained alaskitic rock is exposed in secs. 34 and 35, T. 35 N., R. 40 E. and in secs. 2 and 3, T. 34 N., R. 40 E. The rock is composed of graphic intergrowths (not easily seen in hand sample) of quartz, sodic plagioclase, and K-feldspar; biotite is the only mafic mineral and makes up <1 percent of rock. Miarolitic cavities and small (about 2.5 cm in diameter) pods of coarser grained rocks are present in most of the rock.

An isolated body, exposed on the northeast flank of Dunn Mountain, contains muscovite and probably is not part of the Starvation Flat Quartz Mountain (F. K. Miller, USGS, oral commun., 1986) but is included in this pluton in this report.

Concordant hornblende-biotite K-Ar ages (nos. 42 and 43, Table 5) indicate the Starvation Flat Quartz Monzonite is Cretaceous. A Pb-alpha age for zircon (no. 41, Table 5) also suggests a Cretaceous age.

Kia_n

Monzogranite near Narcisse Creek (Cretaceous)--Leucocratic biotite monzogranite to granodiorite (F. K. Miller, USGS, written commun., 1990) consisting of pink and white K-feldspar phenocrysts as much as 8 cm long (Miller and Clark, 1975) in a medium- to coarse-grained groundmass consisting of biotite, plagioclase, quartz, and accessory magnetite, sphene, apatite, zircon, and pyrite (N. L. Joseph, DGER, written commun., 1990). Most of this pluton is exposed north of the map area in the Colville 1:100,000-scale quadrangle. Even though the monzogranite is porphyritic and contains only sparse hornblende, its groundmass texture and mineralogy are similar to those of the Starvation Flat Quartz Monzonite (Kia_s). The monzogranite near Narcisse Creek yielded a K-Ar biotite age of 104.5 Ma from rock north of the map area (Miller and Engels, 1975), indicating it is Cretaceous.

Ji_l

Lane Mountain pluton (Middle Jurassic)--Gray porphyritic biotite-hornblende granodiorite to quartz monzodiorite (F. K. Miller, USGS, oral commun., 1988) consisting of pale-tan K-feldspar phenocrysts 2-6 cm long in a coarse- to medium-grained groundmass. Hornblende is typically more abundant than biotite (Miller and Engels, 1975); apatite and sphene are the most abundant accessory minerals. The rock has an average modal composition of Q20:A22:P58 (F. K. Miller, USGS, oral commun., 1988). Some parts of the pluton are crudely foliated, and in most areas the pluton is cut by leucocratic dikes. The pluton intruded strata of the Upper Proterozoic Windermere Group (Zmm_m, Zmv_h) and the Lower Cambrian-Upper Proterozoic Addy Quartzite (€Zq_a). Concordant biotite-hornblende K-Ar ages (nos. 44-46, Table 5) indicate that the Lane Mountain pluton is Middle Jurassic.

Precambrian Dikes and Sills

Zib

Basic intrusive dikes and sills (Upper Proterozoic)--Dikes and sills of metabasalt and metagabbro. Metabasalt is typically aphyric and composed of altered plagioclase, mafic minerals altered to biotite, and partially altered ilmenite and magnetite; some dikes contain talc, rutilated quartz, and pyrite porphyroblasts. Metagabbro has an average grain size of 2 mm and is composed of 50-70 percent altered plagioclase (An_{46}), 30-50 percent altered clinopyroxene, $\leq$2 percent altered ilmenite, and sparse altered hornblende and olivine (Evans, 1987). Most rock is phyllitic or sheared. These dikes and sill are present only west of the Jumpoff Joe fault. Dikes ranging from 5 m to 550 m wide cut strata of all the formations in the Middle Proterozoic Deer Trail Group (Yar_b, Yq_b, Ycb_s, Yar_m, Ycb_e, Yq_t, Yar_t) and the conglomerate member of the Upper Proterozoic Huckleberry Formation (Zcg_h). Sills(?) of basic intrusive rock similar to the metabasalt and metagabbro dikes are present at or near the top of the Middle Proterozoic Edna Dolomite (Ycb_e) almost everywhere the top of the formation is exposed; these sills(?) may represent flows of Middle Proterozoic age, but no extrusive features were observed (Miller and Whipple, 1989). Except for the possible flows near the top of the Edna Dolomite, the basic intrusive dikes and sills are considered to represent feeder dikes for the flows of the greenstone member of the Huckleberry Formation (Campbell and Loofbourow, 1962; Evans, 1987; Miller and Clark, 1975) and thus they are assigned a Late Proterozoic age.

Yib

Metadiorite and metagabbro sills (Middle Proterozoic)--Sills of slightly to completely recrystallized, fine- to medium-grained dark-green to black metadiorite and metagabbro. Most rock is composed of >50 percent hornblende, <5 percent quartz, and minor biotite and opaque minerals; most quartz and at least some hornblende were probably derived from metamorphism of pyroxene (Miller, 1982). The modal composition of the rock ranges from diorite to gabbro; chemically, the composition is tholeiitic basalt (Miller, 1974a, 1974c, 1974d, 1982). Sills >100 m thick are typically differentiated to some degree; the upper two-thirds of some sills is pegmatitic or coarse grained and leucocratic. Sills range from a few meters to as much as 600 m thick, but they average about 60 m thick.

Most of the sills intruded the Middle Proterozoic Prichard Formation (Ymsp), but at least one sill (not shown on Plate I) is in the Burke Formation (Yms_{bf}) (Miller, 1974a). Minimal contact metamorphic effects are evident in the country rock. Many sills are in the Precambrian heterogeneous metamorphic rocks (p€hm); the lateral extent of these sills is unknown, as indicated by open ends on the Plate I. Except for the sills between Nelson Peak and Goddards Peak, sills in the Prichard Formation are not as recrystallized as those in the heterogeneous metamorphic rocks (Miller and Clark, 1975). The extensively recrystallized sills in the heterogeneous metamorphic rocks contain garnet porphyroblasts.

Zartman and others (1982) report a U-Pb zircon age of 1,433 Ma from the Crossport C sill near Eastport, Idaho (northeast of the map area); they considered the age to be the age of emplacement. The Crossport C sill horizon is in the lower to middle part of the Prichard Formation (Yms_p). Most sills in the map area lie at a similar stratigraphic horizon and were probably emplaced at nearly the same time as the Crossport C sill.

Metamorphic Rocks

Kog_n

Newman Lake Gneiss (Cretaceous)--Medium-grained, medium- to dark-gray biotite-quartz-plagioclase-K-feldspar (Miller, 1974d) orthogneiss of granodioritic composition (Rhodes, 1984; Rhodes and Hyndman, 1984); muscovite (<1%), allanite, zircon, apatite, and opaque minerals are the most abundant accessory minerals (Miller, 1974d). The fairly homogeneous gneiss is characterized by white K-feldspar megacrysts as much as 10 cm long (Armstrong and others, 1987; Rhodes, 1984; Rhodes and Hyndman, 1984; Weis, 1968; Weissenborn and Weis, 1976); the K-feldspar megacrysts decrease in size from south to north (Weissenborn and Weis, 1976). The gneiss has a gentle west-dipping, slightly to well-developed mylonitic foliation and a ubiquitous mylonitic lineation (70°E) in the plane of foliation. Lineation is defined by streaked-out biotite and is well developed in the south but is progressively less distinct northward (Miller, 1974d).

The contact with the deformed granite of Mount Spokane (Kog_{ms}) and the Hauser Lake Gneiss (p€bg_h) is diffuse and gradational. Within 300-600 m of the contact, the Newman Lake Gneiss contains numerous pods of rock resembling Hauser Lake Gneiss. Metamorphism and deformation preclude determination of the contact relations, but the contact is considered intrusive (Armstrong and others, 1987; Miller, 1974d; Rehrig and others, 1987; Weissenborn and Weis, 1976). About 3 km north of Tweedie, leucocratic plutonic rocks of the Scotia area (TKiaa) may be Newman Lake Gneiss intensely injected by leucocratic dikes and sills.

Because the Newman Lake Gneiss yields zircon crystals and isotopic ratios similar to those yielded by granite of Mount Spokane, some workers consider the protolith to have been emplaced during the Cretaceous (Armstrong and others, 1987; Rehrig and others, 1987); subsequent to emplacement, the intrusive rock was metamorphosed, probably during mylonitization associated with the Spokane dome (Rhodes, 1984; Rhodes and Hyndman, 1984). The gneiss may be a deformed border phase of the granite of Mount Spokane. Other workers consider the gneiss to be Precambrian (Miller, 1974d; Weis, 1968; Weissenborn and Weis, 1976).

p€hm

Heterogeneous metamorphic rocks (Precambrian)--Quartz-mica schist, mica schist, micaceous meta quartzite, amphibolite, and minor hornfels, gneiss, and migmatite; all varieties of rock are thoroughly recrystallized. Quartz, plagioclase, muscovite, and biotite are the most abundant mineral constituents of the schist; garnet is present in most amphibolite and schist; epidote-group minerals are common in the hornfels. Some rocks contain sillimanite and andalusite. These heterogeneous metamorphic rocks are typically well layered and have slightly to well-developed foliation; some rock is mylonitic (Armstrong and others, 1987). The rocks display small-scale folds whose axes parallel the strike of foliation, but large-scale folds and faults are not recognizable (Miller, 1974d). South of the Newport fault, abundant dikes and sills of the leucocratic plutonic rocks of the Scotia area (TKiaa) cut the metamorphic rocks.

The contact with the Phillips Lake Granodiorite ($Kiat_p$) is typically migmatitic over a zone as much as 300 m wide; adjacent to the Phillips Lake Granodiorite the unit consists of as much as 30 percent plutonic rock (Miller, 1974b, 1974c). Intrusive rock of the Phillips Lake Granodiorite probably is present at shallow depths beneath the heterogeneous metamorphic rocks. Parts of the unit are similar to the Hauser Lake Gneiss ($pCbg_h$); some rock is probably intensely metamorphosed strata of the Prichard Formation (Yms_p) (Harms, 1982; Miller, 1974b, 1974c, 1974d; Miller and Clark, 1975). West of the Newport fault, the contact between the Prichard Formation and the heterogeneous metamorphic rocks is gradational over a zone as much as 1.6 km wide; eastward from the contact the degree of recrystallization progressively increases to the point where the protolith of the metamorphic rocks cannot be determined.

Armstrong and others (1987) report a Rb-Sr modal age of 1,450 Ma (no. 47, Table 5) for the gneissic rock at Davis Lake; even though the model age is near the maximum age of about 1,570 Ma (Cressman, 1988) for the beginning of Prichard-age deposition, the gneiss at Davis Lake is interpreted to be pre-Belt basement.

$pCbg_h$

Hauser Lake Gneiss (Precambrian)--Heterogeneous mixture of banded gneiss, migmatitic gneiss and pegmatite, quartz-mica schist, and amphibolite. Rusty weathering quartz-feldspar-muscovite-biotite-sillimanite gneiss consists of bands typically $\leq$0.6 m thick. Most rock contains unevenly distributed garnet. South of the map area the gneiss contains kyanite, and in some exposures kyanite, sillimanite, and andalusite occur together (Rhodes, 1984; Rhodes and Hyndman, 1984). Schist layers are $\leq$0.3 m thick, and some layers are composed almost entirely of biotite and muscovite. Garnet-bearing amphibolite layers and boudins <30 m thick are common. The unit contains abundant layers, lenses, pods, dikes, and irregular bodies of igneous-like quartzofeldspathic gneiss and pegmatite with mafic selvages (Armstrong and others, 1987; Rhodes, 1986; Rhodes and others, 1989; Weis, 1968); the leucocratic, migmatitic gneiss and pegmatitic bodies probably formed as a result of partial melting during high-grade metamorphism prior to mylonitic deformation (Rhodes, 1986; Rhodes and others, 1989). The rock typically has a well-developed, west-dipping mylonitic foliation defined by alignment of micas; a ubiquitous lineation (70°E), defined by the orientation of sillimanite crystals, elongate mineral grains, and oriented striations, lies in the plane of foliation. The 1,600-m thickness (Miller, 1974d) of Hauser Lake Gneiss exposed in the map area is in the mylonitic zone of the Spokane dome; in some exposures an older crystalloblastic foliation is preserved as rootless, intrafolial isoclinal folds (Rhodes, 1984, 1986; Rhodes and Hyndman, 1984).

Cross-cutting relations, Rb-Sr isochron ages, U-Pb concordia ages, and Sr isotopic composition suggest to Armstrong and others (1987) that the Hauser Lake Gneiss is pre-Belt Supergroup basement and is about 1.5 Ga to 2.0 Ga. The Belt Supergroup - pre-Belt basement contact may be in the Hauser Lake Gneiss but obscured by high-grade metamorphism (Rhodes, 1986). Mineralogy, layering, rusty weathering, and the presence of amphibolite layers led other workers (Griggs, 1966, 1973; Miller, 1974d; Weissenborn and Weis, 1976) to consider the Prichard Formation (Ymsp) the most likely protolith of the unit.

Tectonic Rocks

tz

Tectonic zone--The unit is shown on Plate I where the characteristic features of the rock are produced by tectonic deformation and where the destruction of the primary features precludes assignment of the rock to any one lithologic unit. Tectonic zones are shown on Plate I in five areas: along the Newport fault, along the northern extension of the Jumpoff Joe fault, on the west flank of Eagle Mountain, and east and southeast of the town of Newport.

The tectonic zone of the Newport fault includes an upper zone of chlorite microbreccia and a lower zone of foliated rock (Harms, 1982). The upper zone of chlorite microbreccia consists of brittlely deformed cataclastic rock lacking an ordered fabric and is shown as tz on Plate I (F. K. Miller, USGS, oral commun., 1988). The lower zone of foliated rock consists of ductilely deformed mylonitic rock and is shown on Plate I by a diagonal line overprint. Where ductilely deformed rock is overprinted by brittle deformation, it is included in the brittle zone (tz).

The mineral composition and texture of the chlorite microbreccia are extremely consistent, regardless of protolith. This microbreccia is characterized by its green color, lack of fabric, and extremely fine grain size; typically white, internally broken feldspar clasts float in the green, aphanitic matrix. The rock is massive, silicified, and resistant to erosion. Ductile deformation is most intense just below the microbreccia zone. Over the width of the ductile zone, deformation progressively decreases in intensity to the point where only metamorphic (crystalloblastic) and igneous (crystalline) textures are visible. Mesoscopically visible deformation has a minimum width of 15 m in the western segment of the zone of foliated rock; it ranges between 75 m and 425 m in the southern and eastern (east of the map area) segments (Harms, 1982). Ductile deformation is visible on a microscopic scale far beyond the mesoscopic deformation The attitude of foliation conforms to the attitude of the Newport fault. Lineation is defined by preferred orientation of acicular minerals in the plane of foliation.

The Newport fault is a moderately low to low-angle detachment fault juxtaposing an upper plate of low-grade metasedimentary rock and plutonic rock against a lower plate of high-grade metamorphic rock and plutonic rock. Harms (1982) determined the Newport fault plunges north and in three dimensions is spoon-shaped (concave upward).

The Eocene age of deformation along the tectonic zone is constrained by the Eocene age of the Silver Point Quartz Monzonite (Eia_s), which is cut by the zone. The Eocene age of the syntectonic basin-fill of the Sanpoil Volcanics and the Tiger Formation also constrains the age of deformation along the Newport fault.

At the north end of the Jumpoff Joe fault a tectonically deformed zone consisting of cataclastic and mylonitic rock is as much as 100 m wide and extends from sec. 31, T. 34 N., R. 41 E., southwest of Bayley Lake, northeastward to sec. 10, T. 34 N., R. 41 E. (Miller and Clark, 1975). Near Bayley Lake, rock of the Phillips Lake Granodiorite ($Kiat_p$) is irregularly foliated to well foliated; foliation strikes north-northeast and dips northwest at 30°-40°. Foliation is defined by crude alignment of micas. Biotite is chloritic. Some rock in the tectonic zone is fine grained and green and has no apparent oriented fabric. Rounded and broken feldspar and quartz clasts float in a chloritic matrix; sulfide minerals are finely disseminated throughout this rock. The rock is similar in appearance to the chlorite miocrobreccia in the Newport fault zone except it is paler green.

The zone of tectonically deformed rock is probably a result of re-activation of the Jumpoff Joe fault during Eocene extensional tectonism (F. K. Miller, USGS, oral commun., 1989).

A zone of intensely sheared rock lies on the western flank of Eagle Mountain (Miller and Clark, 1975), and areas of cataclastic rock crop out in the Silver Point Quartz Monzonite (Eia_s) in sec. 28, T. 31 N., R. 45 E. and just east of Newport along the Pend Oreille River (Miller, 1974d).

bx

Tectonic breccia--Monolithologic breccia exposed near the northern boundary of the map area and southeast of Calispell Lake; both areas are in the upper plate of the Newport fault. In northern exposures, clasts consist of Paleozoic quartzite, phyllite, and carbonate rocks; in the exposures southeast of Calispell Lake the brecciated rock is a fine-grained quartzite that is probably part of the Belt Supergroup. Clasts are angular and range in size from a few centimeters to house size and are surrounded by a matrix of interlocking grains of comminuted rock. The breccia has no internal fabric or stratification. The western contact of the northern breccia body with chlorite microbreccia of the Newport fault zone is sharp; the eastern contact with undeformed rock is covered but is probably gradational. The tectonic breccia is probably not a continuous body but probably consists of anastomosing seams in unbrecciated strata; rocks in the upper plate were probably brecciated during movement on high-angle listric faults formed during displacement on the Newport fault (Harms, 1982).

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note: Pba should be Pb-alpha, Greek Letter

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Table 1. Isotopic ages of sedimentary, volcanic, and metavolcanic rocks and deposits in the Chewelah 1:100,000-scale quadrangle

Unit	Map symbol	Map loc. no.	Age	Method	Material	Reference	Location	Sample no.
postglacial lacustrine deposits	Qla	1	5,870 yr B.P.	^{14}C	charcoal	E. P. Kiver, EWU, written commun., 1988[1]	SE/4NW/4 sec. 2, T.32N., R.43E.	3781
dacite flows of the Sanpoil Volcanics	Evd_s	2	50.4±1.3 Ma 51.0±1.8 Ma	K-Ar	biotite hornblende	Pearson and Obradovich (1977)[2]	center sec. 27, T.33N., R.44E.	A7
tuff	Evt	3	53.0±1.5 Ma	K-Ar	biotite	Pearson and Obradovich (1977)[2]	SE/4NE/4 sec. 9, T.33N., R.44E.	A1
Huckleberry Formation, greenstone member	Zmv_h	4	238 Ma [3]	K-Ar	whole-rock	Miller and others (1973)[4]	48°24' [5] 117°44'	6
		5	415 Ma [3]	K-Ar	whole-rock	Miller and others (1973)[4]	48°25' [5] 117°43'	5
		6	481 Ma [3]	K-Ar	whole-rock	Miller and others (1973)[4]	48°25' [5] 117°43'	4
		7	613 Ma [3]	K-Ar	pyroxene	Miller and others (1973)[4]	48°25' [5] 117°43'	4
		8	688 Ma [3]	K-Ar	plagioclase	Miller and others (1973)[4]	48°24' [5] 117°44'	1
		9	734 Ma [3]	K-Ar	whole-rock	Miller and Engels (1973)[4]	48°25' [5] 117°43'	3
		10	838 Ma [3]	K-Ar	whole-rock	Miller and Engels (1973)[4]	48°25' [5] 117°43'	2
		11	862 Ma [3]	K-Ar	whole-rock	Miller and Engels (1973)[4]	48°24' [5] 117°44'	1
		12	929 Ma [3]	K-Ar	plagioclase	Miller and Engels (1973)[4]	48°25' [5] 117°43'	4

Table 1. Isotopic ages of sedimentary, volcanic, and metavolcanic rocks and deposits in the Chewelah 1:100,000-scale quadrangle (continued)

Unit	Map Symbol	Map loc. no.	Age	Method	Material	Reference	Location	Sample No.
Huckleberry Formation, greenstone member	Zmv_h	13	762±44 Ma	Sm-Nd isochron	whole-rock and 3 pyroxene separates	Devlin and others (1988)[6]	48°25' 117°43'	1
		14	674±212 Ma	Sm-Nd isochron	7 whole-rock samples	Devlin and others (1988)[6]	--[7]	1-7
		15	795±115 Ma	Sm-Nd isochron	7 whole-rock samples and 2 pyroxene separates	Devlin and others (1988)[6]	--[7]	1-7

[1] Sample analyzed at Washington State University's Radiocarbon Dating Laboratory, Pullman, WA. Sample taken and submitted by E. P. Kiver, Eastern Washington University. Sample was counted in a 100 cc detector for about nine days. Sample was equivalent to 120 mg of carbon. Analysis based on a half-life for radiocarbon of 5,570 +/- 30 yr. Zero age is A.D. 1950.

[2] Pearson and Obradovich (1977): No constants reported. Analytical data reported in table 2.

[3] K-Ar ages originally calculated using the "old" constants (refer to note 4) are recalculated using table 2 in Dalrymple (1979). The recalculated ages take into account the "new" constants recommended by the IUGS Subcommission on Geochronology (Steiger and Jaeger, 1977). The effect of the new constants on the ages is non-linear. The maximum error introduced by using Dalrymple's (1979) table 2 is 0.01%, and recalculated ages are no more precise than the number of signifigant digits in the original age. Original error (±) values are not recalculatable.

[4] Miller and others (1973): Constants used--$^{40}K/K_{total} = 1.19 \times 10^{-4}$ mol/mol, $\lambda_\beta = 4.72 \times 10^{-10} yr^{-1}$, $\lambda_\epsilon = 0.585 \times 10^{-10} yr^{-1}$. Analytical data reported in table 1. Although the K-Ar ages have a wide scatter, Miller and others (1973) postulate the [meta]volcanic flows were extruded between 825 Ma and 900 Ma; they propose the scatter of ages resulted from the analyses of materials in which the degree of alteration varied and that the most reliable results are from the least altered specimens. Devlin and others (1985) conclude the Rb-Sr system of the sampled rock was disturbed implying that the K-Ar system was also disturbed and as a consequence, all K-Ar ages are suspect.

[5] Sample locations originally shown in Miller and others' (1973) figure 3. Longitude and latitude are from Engels and others (1976, sheet 2) and are rounded to the nearest minute.

[6] Devlin and others (1988): $^{147}Sm = 6.54 \times 10^{-12} yr^{-1}$. Analytical data reported in table 1 for whole-rock samples and in table 2 for pyroxene separates. Devlin and others (1988, p. 1910) conclude, of the three Sm-Nd ischron age estimates, the whole-rock-pyroxene separate age of 762±44 Ma from the least altered basalt sample (sample no. 1) is the most reliable.

[7] Devlin and others' (1988) sample nos. 1 through 7 are the same samples from the same locations shown in Devlin and others' (1985) table 1. Sample no. 1 was taken from the top of a flow located at about 48°25'latitude and 117°43' longitude; sample no. 2 was taken from about 40 cm below the top of the flow from the same location; sample no. 3 was taken from about 4 m below the top of the flow from the same location. Sample no. 4 was taken from a different location than samples 1 through 3 but still about 48°25' latitude and 117°43' longitude. Both sample nos. 5 and 6 were taken south of the location of sample nos. 1, 2, and 3; lastly, sample no. 7 was taken from the "Irene volcanic formation, collected along Canada Route 3, southern British Columbia" (Devlin and others, 1985, table 1). Because the age determinations for location nos. 14 and 15 were made by using more than one sample from more than one locality, nos. 14 and 15 are shown on Plate I with an open triangle. For this report, latitude and longitude, as reported by Engels and others (1976, sheet 2), have been rounded to the nearest minute.

Table 2. Major oxide analyses of igneous rocks from the Chewelah 1:100,000-scale quadrangle

Sample no.	Map symbol	Subsection	Sec.	Twp.	Rge.	SiO_2	Al_2O_3	TiO_2	FeO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5
3543334GZ	$Kiat_p$?	SW/4NW/4NE/4	33	35	43E	57.81	16.64	1.29	7.73	0.16	5.26	4.02	4.37	2.34	0.36
3241186DZ	$JTrii_r$?	NW/4NE/4SW/4	18	32	41E	62.09	17.96	0.56	5.70	0.11	5.60	1.57	3.00	3.15	0.26
3240358BZ	Eva	NW/4SW/4SW/4	35	32	40E	59.51	15.67	0.91	5.79	0.08	6.12	4.65	3.26	3.52	0.50
3140226CZ	Ji_l	SW/4NW/4SW/4	22	31	40E	62.98	18.34	0.52	4.38	0.11	4.57	1.01	4.25	3.64	0.22
3140211CZ	Mv_{gN2}	SE/4NW/4SE/4	21	31	40E	56.64	13.98	2.12	11.66	0.19	6.80	3.40	1.72	3.11	0.37
3139368DZ	Ji_l	NW/4NW/4SW/4	36	31	39E	63.38	18.77	0.43	3.27	0.10	4.46	0.83	4.19	4.42	0.16
3139365FZ	Ji_l	NE/4SE/4NW/4	36	31	39E	64.26	18.56	0.45	3.78	0.11	4.87	1.07	1.89	4.83	0.18
2941116GZ	Eia_s	SW/4NE/4NW/4	11	29	41E	65.74	15.39	0.65	3.98	0.07	3.66	2.36	4.04	3.79	0.30

Table 3. Trace element analyses of igneous rocks from the Chewelah 1:100,000-scale quadrangle

Sample no.	Map symbol	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn
3543334GZ	$Kiat_p$?	25	44	21	191	1300	250	496	71	49	33.0	18	10	89
3241186DZ	$JTrii_r$?	6	3	13	80	489	112	788	192	30	17.0	20	8	52
3240358BZ	Eva	134	262	16	124	1442	69	1062	213	18	15.0	20	38	77
3140226CZ	Ji_l	13	5	9	53	1339	138	1007	218	28	19.0	21	9	64
3140211CZ	Mv_{gN2}	0	15	29	300	702	48	323	184	36	15.0	25	15	119
3139368DZ	Ji_l	11	0	11	46	1337	143	1042	178	20	18.0	20	22	61
3139365FZ	Ji_l	8	0	11	56	271	92	943	200	21	19.0	69	0	0
2941116GZ	Eia_s	29	42	12	75	1330	114	1017	229	18	16.0	20	9	58

Table 4. Results of recent conodont sampling in the Chewelah 1:100,000-scale quadrangle

Map loc. no.	Sample no. (USGS Coll. No.)	Map symbol	Conodonts	Age	Location	Collected by	Identifier
1	75FP-624F (26267-PC)	Ccb	Pb element of Siphonodella sp. indet., Patrognathus? sp. indet.	Early Mississippian (Kinderhookian)	Near center, sec. 27, T. 30 N., R. 40 E.	F. G. Poole (USGS)	A. G. Harris (USGS)
2	A28.9 (29322-PC)	Ccb	"Bispathodus stabilis" Hindeodus sp., Taphrognathus sp.	Late Mississippian (early Meramecian)	Near center, sec. 27, T. 30 N., R. 40 E., 28.9 m above base	Mehemed Gheddida (EWU)	B. R. Wardlaw (USGS)
3	A32.0 (29323-PC)	Ccb	Hindeodus pulcher (Branson & Mehl), Taphrognathus sp.	Late Mississippian (early Meramecian)	Near center, sec. 27, T. 30 N., R. 40 E., 32.0 m above base	Mehemed Gheddida (EWU)	B. R. Wardlaw (USGS)
4	A145.0 (29324-PC)	Ccb	"Bispathodus stabilis" Cavusgnathus sp., Hindeodus scitulus (Hinde), Taphrognathus? sp.	Late Mississippian (early Meramecian)	Near center, sec. 27, T. 30 N., R. 40 E., 145.0 m above base	Mehemed Gheddida (EWU)	B. R. Wardlaw (USGS)
5	A149.0 (29325-PC)	Ccb	Hindeodus cristulus (Youngquist & Miller)	Late Mississippian (early Chesterian)	Near center, sec. 27, T. 30 N., R. 40 E., 149.0 m above base	Mehemed Gheddida (EWU)	B. R. Wardlaw (USGS)
6	A153.1 (29326-PC)	Ccb	Hindeodus cristulus (Youngquist & Miller) Hindeodus scitulus? (Hinde)	Late Mississippian (early Chesterian)	Near center, sec. 27, T. 30 N., R. 40 E., 153.1 m above base	Mehemed Gheddida (EWU)	B. R. Wardlaw (USGS)
7	BB2940168hb (29909-PC)	Ccb	Bactrognathus sp., Hindeodus aff. H. cristulus (Youngquist & Miller), Kladognathus sp. indet., "Ozarkodina" sp. indet., Windsorgnathus? sp.	Late Mississippian (late Meramecian-early Chesterian with redeposited Osagean elements)	NW/4NW/4NW/4. sec. 16, T. 29 N., R. 40 E.	B. B. Bunning (formerly DGER)	A. G. Harris
8	2940162eZ (30115-PC0	Ccb	Cavusgnathid fragments Gnathodid or idiognathodid fragment	Late Mississippian to Early Permian (Chesterian-Wolfcampian)	SW/4SE/4NE/4, sec. 16, T. 29 N., R. 40 E.	S. Z. Waggoner (DGER)	A. G. Harris
9	2940162eZb (30180-PC0	Ccb	Hindeodus aff. H. crassidentatus (Branson & Mehl), "Ozarkodina" sp. indet.	Early to Late Mississippian (Kinderhookian-Meramecian)	SW/4SE/4NE/4, sec. 16, T. 29 N., R. 40 E.	S. Z. Waggoner (DGER)	A. G. Harris (USGS)
10	3040018cZ (30116-PC)	Ccb	Hindeodus sp. indet.	Early to Late Mississippian to Permian (probably Mississippian)	SW/4NW/4SW/4, sec. 1, T. 30 N., R. 40 E.	S. Z. Waggoner (DGER)	A. G. Harris (USGS)
11	3141184aZ (11869-SD)	Ccb	Palmatolepis quadrantinodosa inflexa Muller, Pelekysgnathus? sp. indet., Polygnathus semicostatus Branson & Mehl, Polygnathus sp. indet.	Late Devonian (early Famennian)	SW/4SW/4SE/4 sec. 18, T. 31 N., R. 41 E.	S. Z. Waggoner (DGER)	A. G. Harris (USGS)

Table 5. Isotopic ages of intrusive and metamorphic rocks in the Chewelah 1:100,000-scale quadrangle. Refer to Table 1 for map location nos. 1 through 15.

Unit	Map symbol	Map loc. no.	Age (Ma)	Material	Method	Reference	Location	Sample no.
				Hypabyssal Dikes				
dikes, undivided	Ei	16	48.0[1] 48.5[1]	biotite hornblende	K-Ar	Engels and others (1976)[2]	48°01' 117°17'	294
				Plutonic rocks in the upper plate of the Newport fault				
Galena Point Granodiorite	Kia_g	17	101[1]	biotite	K-Ar	Miller and Engels (1975)[3]	48°28' 117°08'	74
Blickensderfer Quartz Monzonite	$Kiat_b$	18	101[1] 102[1]	biotite muscovite	K-Ar	Miller and Engels (1975)[3]	48°25' 117°08'	73
Silver Point Quartz Monzonite	Eia_s	19	39±4	3 whole-rock samples:	Rb-Sr isochron	Armstrong and others (1987)[4]		
				granite			48°05' 117°19'	RS-77-6
				aplite dike			48°06' 117°19'	RS-77-6
				aplite dike			48°05' 117°19'	RS-77-6
				Plutonic rocks in the lower plate of the Newport fault				
Silver Point Quartz Monzonite	Eia_s	20	46±2	1 whole-rock sample and 1 separate:	Rb-Sr isochron	Armstrong and others (1987)[4]		
				granite biotite			48°05' 117°19'	RS-77-6
Silver Point Quartz Monzonite	Eia_s	21	47.9[1] 48.0[1]	biotite hornblende	K-Ar	Miller and Engels (1975)[3]	48°12' 117°17'	69
		22	49.3[1] 52.3[1]	biotite hornblende	K-Ar	Miller and Engels (1975)[3]	48°08' 117°17'	68
		23	51[5] 62[5,6]	biotite hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°02' 117°36'	10
quartz monzodiorite	Eii	24	50[1] 65[5,6]	biotite hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°02' 117°43'	12
fine-grained quartz monzonite	Eiqm	25	51[5] 327[5,6]	biotite hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°04' 117°40'	13
		26	300[5,6]	hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°04' 117°40'	14
		27	52[5] 199[5,6]	biotite hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°04' 117°40'	15

Table 5. Isotopic ages of intrusive and metamorphic rocks in the Chewelah 1:100,000-scale quadrangle. Refer to Table 1 for map location nos. 1 through 15. (Continued)

Unit	Map symbol	Map loc. no.	Age (Ma)	Material	Method	Reference	Location	Sample no.
Fan Lake Granodiorite	Kia_f	28	49.2[1,8] 87.4[1]	biotite hornblende	K-Ar	Miller and Engels (1975)[3]	48°02' 117°15'	67
		29	95.7[1] 97.5[1]	biotite hornblende	K-Ar	Miller and Engels (1975)[3]	48°03' 117°24'	77
alaskite intrusive	Kiaa	30	80[5,7]	muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°04' 117°34'	16
Phillips Lake Granodiorite	$Kiat_p$	31	49.7[1,8] 51.1[1,8]	biotite muscovite	K-Ar	Miller and Engels (1975)[3]	48°26' 117°23'	75
		32	53[5,8] 59[5,8]	biotite muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°23' 117°35'	7
		33	57[5,8] 69[5,8]	biotite muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°24' 117°37'	5
two-mica monzogranite of the Nelson Peak area included in the Phillips Lake Granodiorite	$Kiat_p$	34	56[5,8] 57[5,8]	biotite muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°12' 117°30'	17
leucocratic dike associated with the Phillips Lake Granodiorite	$Kiat_p$	35	61[5,8] 86[5,8]	biotite muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°30' 117°40'	8
aplite associated with the Phillips Lake Granodiorite	$Kiat_p$	36	65[5,8]	biotite muscovite	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°24' 117°37'	18
Flowery Trail Granodiorite	JT ii_f	37	66[5,8] 146[5,8]	biotite hornblende	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°18 117°34'	3
		38	86[5,8] 187[5,8]	biotite hornblende	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°18' 117°37'	2
		39	100[5,8] 198[5,8]	hornblende	K-Ar	Engels <u>in</u> Miller and Clark (1975)[7]	48°17' 117°39'	1
			<u>Plutonic rocks west of the Jumpoff Joe fault</u>					
Midnite mine pluton	Kia_m	40	78.1[1]	biotite	K-Ar	Miller and Engels (1975)[3]	48°01' 117°52'	82
Starvation Flat Quartz Monzonite	Kia_s	41	99	zircon	Pb-alpha	Larsen and others (1958)[9]	48°29' 117°53'	G-115

Table 5. Isotopic ages of intrusive and metamorphic rocks in the Chewelah 1:100,000-scale quadrangle. Refer to Table 1 for map location nos. 1 through 15. (Continued)

Unit	Map symbol	Map loc. no.	Age (Ma)	Material	Method	Reference	Location	Sample no.
Starvation Flat Quartz Monzonite body at the north end of Huckleberry Mountain	Kia_s	42	100[1]	biotite	K-Ar	Miller and Engels (1975)[3]	48°18' 117°57'	84
Starvation Flat Quartz Monzonite	Kia_s	43	100[5] 99[5]	biotite hornblende	K-Ar	Engels in Miller and Clark (1975)[7]	48°28' 117°45'	4
Lane Mountain pluton	Ji_l	44	156[1] 169[5]	biotite hornblende	K-Ar	Miller and Engels (1975)[3]	48°10' 117°49'	83
		45	160 162	biotite hornblende	K-Ar	F. K. Miller (USGS oral commun., 1988)[10]	SE/4SW/4 sec. 30, T. 31 N., R. 40 E.	–
		46	169[5] 173[5]	biotite hornblende	K-Ar	F. K. Miller (USGS oral commun., 1988)[11]	SW/4NW/4 sec. 13, T. 31 N., R. 39 E.	–
				Metamorphic rocks				
heterogeneous metamorphic rocks	p€hm	47	1,450	1 whole-rock sample and bulk-Earth initial: "mylonitic" gneiss	Rb-Sr isochron	Armstrong and others (1987)[4]	48°14' 117°17'	DL-C

[1] Ages recalculated by F. K. Miller (USGS, written commun., 1990).

[2] Engels and others (1976): Analytical data and latitude and longitude reported in table 1; longitude and latitude rounded to the nearest minute. No constants were reported so ages are not recalculated for this report. Age estimates originally reported in Miller (1974c).

[3] Miller and Engels (1975): Constants used–$^{40}K/K_{total}$ = 1.19 x 10^{-4} mol/mol, λ_β = 4.72 x $10^{-10}yr^{-1}$, and λ_ϵ = 0.584 x $10^{-10}yr^{-1}$. Analytical data reported in table 1. Map location numbers 17 and 18 originally reported in Miller (1974a), numbers. 21, 22, and 29 originally reported in Miller (1974c).

[4] Armstrong and others (1987): ^{87}Rb = 1.42 x $10^{-11}yr^{-1}$. Analytical data and longitude and latitude reported in appendix 1; longitude and latitude rounded to the nearest minute. Because the age determination for locality number 19 was made by using more than one sample from more than one locality, the location is shown on Plate I with an open triangle.

[5] K-Ar ages, originally calculated using the "old" constants of $^{40}K/K_{total}$ = 1.19 x 10^{-4} mol/mol, λ_β = 4.72 x $10^{-10}yr^{-1}$, and λ_ϵ = 0.585 x $10^{-10}yr^{-1}$, are recalculated using table 2 in Dalrymple (1979). The recalculated ages take into account the "new" constants recommended by the IUGS Subcommission on Geochronology (Steiger and Jaeger, 1977). The effect of the new constants on the ages is non-linear. The maximum error introduced by Dalrymple's (1979) table 2 is 0.01%, and recalculated ages are no more precise than the number of significant digits in the original age. Original error (±) values are not recalculatable.

(Footnotes continued on next page)

Table 5 footnotes, continued

[6] Engels (<u>in</u> Miller and Clark, 1975) concludes hornblende is inherited from older rocks and thus yields older, discordant age estimates. Most inherited hornblende occurs in clusters of crystals, contains pyroxene cores, and displays abnormal optical properties.

[7] Engels (<u>in</u> Miller and Clark, 1975): Constants used–$^{40}K/K_{total}$ = 1.19 x 10^{-4} mol/mol (1.19 x 10^{-2} atom %), $\lambda_{\beta} = 4.72 \times 10^{-10} yr^{-1}$, and $\lambda_{\epsilon} = 0.585 \times 10^{-10} yr^{-1}$. Analytical data reported in table 3. The ages are recalculated according to Dalrymple (1979, table 2). Latitude and longitude are from Miller and Engels (1975) except for the longitude and latitude for Map location number 36, which is from Engels and others (1976) and is rounded to the nearest minute.

[8] Miller and Engels (1975) believe the K-Ar ages are partially or totally reset due to Ar loss resulting from an Eocene thermal event. However, Price and others (1981) consider the regional trend of discordant age determinations to reflect sequential cooling instead of argon loss and resetting due to an Eocene thermal event; they interpret the concordant older ages to represent secular (slow and gradual) cooling in parts of the plutons and the younger concordant ages to represent rapid uplift, resulting from tectonic denudation, of parts of the plutons through the K-Ar blocking temperatures. The discordant ages from co-existing mineral pairs represent the horizon in the plutons where the boundary between secular cooling and rapid cooling or quenching occurs. For this report, older age estimates are still considered to approach the age of emplacement as suggested by Engels (<u>in</u> Miller and Clark, 1975) regardless of the mechanism that caused the discordance.

[9] Larsen and others (1958): Assuming a Th to U ratio of 1, c for zircon = 2,485 (p. 38). α = 876 per mg per hr and Pb = 35 ppm average (table 11). Longitude and latitude are from Engels and others (1976) and are rounded to the nearest minute.

[10] F. K. Miller (USGS, oral commun., 1988): Unpublished age determination. Constants used–$^{40}K/K_{total}$ = 1.19 x10^{-4} mol/mol, $\lambda_{\beta} = 4.72 \times 10^{-10} yr^{-1}$, and $\lambda_{\epsilon} = 0.585 \times 10^{-10} yr^{-1}$. No analytical data reported. The age is recalculated using table 2 in Dalrymple (1979).

[11] F. K. Miller (USGS, oral commun., 1988): Unpublished age determination reported to F. K. Miller (USGS) by R. J. Fleck (USGS). Constants used–$^{40}K/K_{total}$ = 1.167 x 10^{-4} mol/mol, $\lambda_{\beta} = 4.962 \times 10^{-10} yr^{-1}$, and $\lambda_{\epsilon} + \lambda_{\epsilon'} = 0.581 \times 10^{-10} yr^{-1}$ ("new" constants). No analytical data reported.