Geologic Map of the Bonners Ferry 30´ X 60´ Quadrangle, Idaho and Montana

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INTRODUCTION

In this report, Bonners Ferry quadrangle refers to the Bonners Ferry 1:100,000-scale quadrangle, as distinguished from the Bonners Ferry 7.5' quadrangle. The Bonners Ferry quadrangle spans the northernmost part of the Idaho panhandle, extending about 3.5 km into Montana; its northern limit is the United States-Canada boundary.

The bedrock geology of the Bonners Ferry quadrangle consists of sedimentary, metamorphic, and granitic rocks ranging in age from Middle Proterozoic to Eocene. Bedrock units include rocks of (1) the Middle Proterozoic Belt Supergroup, (2) the Middle Proterozoic Deer Trail Group, (3) the Late Proterozoic Windermere Group, (4) miogeoclinal or shelf facies lower Paleozoic rocks, and (5) Mesozoic and Eocene granitic rocks.

The Belt Supergroup, a thick sequence of argillite, siltite, quartzite, and impure carbonate rocks up to 14,000 m thick is found in two noncontiguous sequences in the quadrangle: (1) the Clark Fork-Eastport Sequence east of the Purcell Trench and (2) the Newport Sequence in the hanging wall of the Newport Fault (fig. 1). Only the two lowest Belt formations of the Newport Sequence are found in the Bonners Ferry quadrangle, but these two units are part of a continuous section, which extends southwest of the map area to the town of Newport.

Belt Supergroup rocks of the Clark Fork-Eastport Sequence are separated from those of the Newport Sequence by the Newport Fault, Priest River complex, and Purcell Trench Fault (fig. 1). Some formations of the Belt Supergroup show differences in thickness and (or) lithofacies from one sequence to the other that are greater than those predicted from an empirical depositional model for the distances currently separating the sequences. These anomalous thickness and facies differences suggest that contraction on structures separating the sequences was greater than Eocene extension associated with emplacement of the Priest River complex. In addition to these two Belt sequences, probable Belt Supergroup rocks are present in the Priest River complex as highly metamorphosed crystalline schist and gneiss.

Northwest of the Newport Sequence of the Belt Supergroup is the Deer Trail Group, a distinct Middle Proterozoic sequence of argillite, siltite, quartzite, and carbonate rocks that is lithostratigraphically similar to the Belt Supergroup but separated from all Belt Supergroup rocks by the Jumpoff Joe Fault. Rocks of the Deer Trail Group are pervasively phyllitic and noticeably more deformed than most of the rocks in either of the Belt Supergroup sequences. Lithostratigraphically the Deer Trail Group is equivalent to part of the upper part of the Belt Supergroup (Miller and Whipple, 1989). Differences in lithostratigraphy and thickness between individual Deer Trail and Belt units and between the Deer Trail and Belt sequences as a whole indicate that they were probably much farther apart when they were deposited.

The Windermere Group is a lithologically varied sequence of coarse-grained, mostly immature, clastic sedimentary rocks and volcanic rocks up to 8,000 m thick. It is characterized by extreme differences in thickness and lithofacies over short distances; these differences are interpreted as due to syndepositional faulting associated with initial stages of continental rifting in the Late Proterozoic. Strata of the Windermere Group unconformably overlie only the Deer Trail Group and are nowhere found in depositional contact with Belt Supergroup rocks.

Paleozoic rocks in the Bonners Ferry quadrangle are represented only by a thin, fault-bounded remnant preserved within the Clark Fork-Eastport Belt Supergroup sequence.

Mesozoic granitic rocks underlie at least 50 percent of the Bonners Ferry quadrangle. Most fall into two petrogenetic suites, hornblende-biotite bodies and muscovite-biotite (two-mica) bodies. Both suites are represented in the mid-crustal Priest River complex and in the higher level plutons that flank the complex; by far the majority of plutons in the Priest River complex are two-mica bodies.

Tertiary rocks are restricted to a single small stock, numerous hypabyssal dikes that are too small to show at the scale of the map, and cataclastic rocks related to the Newport Fault.

Quaternary deposits include unconsolidated to poorly consolidated glacial, alluvial, glacial-lacustrine, and landslide units.

STRUCTURE

Rocks within the Bonners Ferry quadrangle record a complex and varied structural history from the Late Proterozoic to the Eocene, one that is characterized by several discrete periods of igneous intrusion, folding, normal and reverse faulting, and repeated reactivation of faults during succeeding periods of faulting.

Major structural features in the quadrangle (fig. 1) include the (1) Kootenay Arc and its associated structures, (2) Jumpoff Joe Fault, (3) Moyie Fault and structures deforming Belt Supergroup sequences, (4) Priest River complex, (5) Purcell Trench Fault, (6) Newport Fault, and (7) Eocene normal faults.

The Kootenay Arc is a broad bend in the regional geologic framework; rocks within the arc comprise a highly faulted and folded, allochthonous sequence of Middle and Late Proterozoic, Paleozoic, and Mesozoic age. The southeastern edge of the arc underlies the northwesternmost part of the Bonners Ferry quadrangle, but only the Middle and Late Proterozoic rocks define it there. These rocks and the structures developed in them have the consistent north-northeast strike that characterizes the arc in the United States. Sharply delineating the east boundary of the Kootenay Arc, the Jumpoff Joe Fault juxtaposes rocks of the arc against partly coeval rocks of the Belt Supergroup that have distinctly different structural and lithostratigraphic characteristics.

Lying east of the Purcell Trench (figs. 1 and 2), is the western part of an extensive, nearly contiguous terrane of Belt Supergroup rocks that extends eastward for over 400 km into Montana. In the Bonners Ferry quadrangle these rocks are cut by numerous high-angle normal and reverse faults that, in contrast to those of the Kootenay Arc, show relatively little preferred orientation. By far the largest fault cutting these Belt rocks is the Moyie Fault, which continues northeast into British Columbia (Benvenuto and Price, 1979) where it converges slightly with the St. Mary Fault. Southeast from the Bonners Ferry quadrangle, the Moyie Fault merges with the Moyie Thrust System of Harrison and others (1992) and Harrison and Cressman (1993).

Much of the central part of the Bonners Ferry quadrangle is underlain by the eastern part of the Priest River complex, which is a heterogeneous intermixture of two-mica granitic rocks and highly recrystallized Middle Proterozoic rocks. The shallowly dipping Eocene Newport Fault separates the midcrustal crystalline rocks of the Priest River complex from an overlying, relatively thin, spoon-shaped, detached flap of essentially unmetamorphosed rocks of the Belt Supergroup and relatively high-level plutons that intrude them (fig. 1). The east boundary of the complex, concealed beneath Quaternary sediments in the Purcell Trench, is the Purcell Trench Fault, inferred to be either an east-dipping detachment fault (Reynolds and others, 1981) or a discontinuous normal fault (Doughty and Price, 2000). Eocene normal faults, associated with unroofing of the Priest River complex and development of the Newport Fault, appear to be the youngest structures affecting rocks in the quadrangle.

Numerous intermediate- to high-level plutons intrude Belt Supergroup rocks that form the hanging walls flanking the east and west sides of the Priest River complex. These plutons, which range in age from Triassic or Jurassic to Eocene, represent four discrete intrusive episodes and underlie about 20 percent of the quadrangle.

Kootenay Arc and its associated structures

The northwesternmost part of the quadrangle is underlain by rocks and structures of the Kootenay Arc, which is a broad bend in the regional stratigraphic and structural framework of the Cordillera north and south of the United States-Canada boundary; it is not an arc in the sense of volcanic arc. The arc extends from the north margin of the Columbia River Basalt Group, about 110 km southwest of the Bonners Ferry quadrangle, through northeastern Washington and northern Idaho to approximately Revelstoke, British Columbia, a distance of about 400 km. Rocks in the Bonners Ferry quadrangle exhibit the characteristics and multiple deformations that Watkinson and Ellis (1987) and Ellis (1986) describe as typical of the Kootenay Arc. Within the quadrangle, pre-Mesozoic rocks in the arc form a highly faulted and folded north-northeast-striking, mainly west-dipping sequence. The north-northeast strike of the rocks and the structures developed in them are characteristic of the trend of the southern part of the Kootenay Arc, most of which lies in the United States. Beginning at about the United States-Canada boundary, the Kootenay Arc makes a broad northward and then northwestward bend.

Deformational episodes affected rocks of the Kootenay Arc in the (1) Late Proterozoic, (2) late Paleozoic to middle Mesozoic, and (3) Eocene; probably more than one episode occurred in the late Paleozoic to middle Mesozoic interval. Except for Eocene faults, most faults in the Kootenay Arc were probably reactivated one or more times after their initial development. Because of this reactivation history, it has not been possible to reliably assign many faults uniquely to discrete episodes of faulting nor to accurately date the time(s) that they were active. This is particularly true for faults of the late Paleozoic to middle Mesozoic episode. In addition to being reactivated, some faults in the arc were folded or crosscut by younger faults during succeeding episodes of deformation.

Few faults within this part of the Kootenay Arc are even moderately well exposed. As a consequence, little is known about the amount or direction of fault dips, which compounds the problem of subdividing or classifying faults into genetically related groups. Lacking information on fault attitudes precludes distinction between normal and reverse faults and limits constraints on structural and stratigraphic interpretations. In the Kootenay Arc, relative motion on faults is indicated mainly by the relative ages of rocks juxtaposed across the fault, except for a few reverse or thrust faults where direct evidence or regional interpretation strongly suggest that younger rocks are faulted over older rocks or where there is relatively good evidence for reactivated faulting.

Late Proterozoic structures are chiefly normal faults associated with continental-scale rifting and deposition of the Late Proterozoic Windermere Group. Devlin and Bond (1988; also see Devlin and others, 1985) convincingly showed that nearby Windermere strata in southern British Columbia were deposited in a rift environment in the Late Proterozoic. In the United States, however, even in areas to the west and southwest, where fault relations are better preserved than they are in the Bonners Ferry quadrangle, direct evidence for the extent of Late Proterozoic faulting is either lacking or ambiguous, because most faults in the Kootenay Arc have been reactivated. Despite reactivation of faults, indirect evidence such as the differences in thickness, lithology, and distribution of Windermere Group units over short distances, in addition to the fact that Windermere units in adjacent fault blocks were deposited on different units of the Deer Trail Group, strongly suggest proximity to basin-margin normal faults and suggest considerable fault activity in the Late Proterozoic (Miller, 1994). Within the quadrangle, only the Jumpoff Joe Fault is specifically identified as probably having been active in Late Proterozoic, although some of the faults in the Kootenay Arc could have been active then.

Most of the faults associated with the Kootenay Arc belong to the late Paleozoic to middle Mesozoic age group and probably represent several discrete episodes of faulting within that time interval. The majority are developed in rocks of the Deer Trail Group and are closely associated with the tight folding that also affects these rocks. Both normal and reverse faults appear to be represented, but the few crosscutting relations found are conflicting, which suggests that there could have been more than one period of reverse faulting and possibly more than one period of normal faulting. Additionally, many of the faults that developed early in the late Paleozoic to middle Mesozoic interval were probably reactivated later in this same time interval and possibly some of them again in the Eocene.

Within the quadrangle, the Mesozoic end of the late Paleozoic to middle Mesozoic age range for these faults is constrained by the Jurassic tonalite and trondhjemite of Continental Mountain, which postdates all but the Eocene faults in the area. Southwest of the quadrangle, the age of faulting is constrained by the Ordovician Ledbetter Slate, which is the youngest unit affected by the late Paleozoic to middle Mesozoic faults (Miller, 1996a). Twenty-five km west of the quadrangle in the Metaline area, rocks as young as Late Devonian are affected (Joseph, 1990). Roback and Walker (1989) suggest that rocks of the Quesnellia Terrane west of the Metaline area were multiply deformed from the Pennsylvanian(?) to the Middle Jurassic and that the youngest deformation of this interval, which they dated at 170 Ma, was associated with the collision of the Quesnellia Terrane. If all late Paleozoic to middle Mesozoic faulting in the Kootenay Arc was associated strictly with this collision, the faulting should have been limited to a relatively narrow time window. Because faulting appears to have occurred over a relatively broad time interval, and some of these faults appear to be much older than others, possibly some are associated with subduction or strike-slip faulting that predated, but is related to, the collision event.

Rocks of the Kootenay Arc are highly folded, chiefly by tight, commonly asymmetric folds that contrast in style and concentration with the more open folds in rocks of the Belt Supergroup sequences. Nearly all of the folds in the Kootenay Arc have axes that range from due north to approximately parallel to the north-northeast strike of the arc. The smaller folds have amplitudes ranging from 1 cm to tens of meters. To the southwest in the Chewelah 30' x 60' quadrangle, larger folds with amplitudes measured in kilometers are developed in Kootenay Arc rocks (Miller, 2001) but larger folds were not recognized or were not developed in the Bonners Ferry quadrangle. In the Chewelah quadrangle, where structural relations in the Kootenay Arc are much better exposed, folding appears to be associated with reverse faulting of the late Paleozoic to middle Mesozoic time interval. In the Continental Mountain area in the Bonners Ferry quadrangle, this folding clearly pre-dates thermal metamorphism associated with the Cretaceous granitoid rocks of the Priest River complex and probably the Jurassic tonalite of Continental Mountain.

Jumpoff Joe Fault

The Jumpoff Joe Fault juxtaposes rocks of the Deer Trail Group against rocks of the Belt Supergroup and is interpreted to be a west-dipping thrust fault. Along its entire length, the fault consistently marks the southeast extent of the Deer Trail Group and appears to define the eastern limit of the Kootenay Arc. The fault extends discontinuously from at least Springdale, Washington, 75 km southwest of the quadrangle, to the north border of the Bonners Ferry quadrangle (fig. 1), but it is exposed at only a few places in that distance. Where it is exposed, the fault appears to have a moderate west dip, but at some places, even though concealed, its approximate trace over irregular topography suggests that it may be folded.

A number of structural and stratigraphic differences in rock assemblages on opposite sides of the Jumpoff Joe Fault indicate it is a complex, multiply reactivated, regional-scale fault that has had a protracted, episodic movement history. These differences across the fault include (1) intensity and style of rock deformation, (2) regional structural trends, (3) contrasting lithostratigraphy of the Deer Trail Group compared to that of the partly coeval Belt Supergroup, (4) occurrence of the Windermere Group only west of the fault, and (5) lithostratigraphy of Paleozoic units (in the Chewelah 30' x 60' quadrangle).

Rocks of the Deer Trail Group west of the Jumpoff Joe Fault are much more strongly deformed and metamorphosed than partly coeval rocks of the Belt Supergroup east of the fault and have a more uniform structural trend than is found in the Belt rocks. West of the Jumpoff Joe Fault the Deer Trail Group is extremely faulted, folded, and cleaved, and most of the rocks are highly phyllitic; east of the fault, rocks of the Belt Supergroup are cut by an order-of-magnitude fewer faults, are essentially unfolded, and are rarely phyllitic. This contrast is particularly evident southwest of the quadrangle away from the metamorphic effects of the Priest River complex. Both regional and small-scale structural elements of the Kootenay Arc have extremely consistent structural trends west of the Jumpoff Joe Fault and vary little from the north-northeast-strike that typifies this part of the arc. East of the fault, the regional structural trend is generally north and is distinctly more variable than the north-northeast structural trend west of the fault, except in areas where the Belt Supergroup rocks are disrupted by Mesozoic plutons.

On the basis of lithostratigraphy, Miller and Whipple (1989) showed that part of the Deer Trail Group is correlative with part of the upper part of the Belt Supergroup; however, they showed that stratigraphic differences between the two sequences on a unit-by-unit basis indicate that the Deer Trail and Belt probably originated at a considerable distance from one another and that the two sequences were subsequently juxtaposed by faulting. In addition, southwest of the quadrangle in the Chewelah 30′ x 60′ quadrangle (Miller, 2001), west of the Jumpoff Joe Fault, the lithostratigraphy of Paleozoic sequences above the Late Proterozoic and Cambrian Addy Quartzite differ markedly from the lithostratigraphy of Paleozoic sequences above the Addy east of the fault.

No rocks of the Windermere Group are known to exist east of the Jumpoff Joe Fault. On the west side of the Jumpoff Joe Fault, in the Chewelah 30′ x 60′ quadrangle, rocks of the Windermere Group unconformably overlie the Deer Trail Group and are unconformably overlain by Late Proterozoic and Cambrian quartzite. East of the fault, only 5 km distance from Deer Trail Group rocks, the Belt Supergroup is unconformably overlain by Late Proterozoic and Cambrian quartzite, and the Windermere Group is everywhere absent. In the northwest corner of the Bonners Ferry quadrangle, the relatively small area of Shedroof Conglomerate is the lower part of a nearly continuous Windermere Group section that is approximately 8,000 m thick (Miller and others, 1999). Although younger rocks are not found depositionally above the Belt Supergroup on the east side of the Jumpoff Joe in the Bonners Ferry quadrangle, 20 km southwest of the quadrangle Late Proterozoic and Cambrian quartzite rests depositionally on the Belt Supergroup within 11 km of the projected trace of the Jumpoff Joe Fault. Here, as at other places, no Windermere Group rocks are found above the Belt Supergroup. Because the Windermere Group is consistently absent east of the Jumpoff Joe Fault, the fault is thought to have originated as a major Late Proterozoic normal fault that bounded the Windermere Group sedimentary wedge (Miller, 1994). Reactivation involving major displacements in late Paleozoic to middle Mesozoic time is thought to have resulted in net contractional movement across the fault.

The Jumpoff Joe Fault in the Bonners Ferry quadrangle separates the same rock assemblages and essentially the same structural regimes that it does to the southwest and, on that basis, is here extended from the Chewelah area to the United States-Canada boundary. The fault is not continuous between these two areas; the two segments are separated by about 35 km of granitic rocks and the Newport Fault.

At the United States-Canada boundary, the Jumpoff Joe Fault is roughly aligned with the St. Mary Fault 55 km to the northeast in British Columbia (fig. 1); the two faults may represent disconnected parts of a single structure (Miller, 1994). In Canada, the Windermere Supergroup is the lateral equivalent of the Windermere Group in the United States, and the Purcell Supergroup is the lateral equivalent of the Belt Supergroup and Deer Trail Group in the United States. The distinction between the Purcell Supergroup and a deformed lithostratigraphic equivalent sequence, such as the Deer Trail Group, is not made in Canada. On the northwest side of the St. Mary Fault, 9,000 m of the Windermere Supergroup unconformably overlie the Purcell Supergroup and are unconformably overlain by Late Proterozoic and Cambrian rocks (Rice, 1941). Southeast of the fault, Late Proterozoic and Cambrian rocks unconformably lie directly on the Purcell

Supergroup. Lis and Price (1976) interpreted this relation to indicate that the St. Mary Fault is a syndepositional Late Proterozoic normal fault that created an elevated sediment source area on its southeast side and a downdropped basin of accumulation on its northwest side. The fault was reactivated with an opposite sense of throw in post-Windermere time.

The intervening area between the Jumpoff Joe and St. Mary Faults is largely underlain by Cretaceous granitic rocks (Archibald and others, 1984) that postdate latest movements on both faults and by a complexly deformed and metamorphosed assemblage of Proterozoic to Mesozoic sedimentary rocks. The Purcell Trench Fault (Purcell-Coeur d'Alene detachment of Rehrig and others, 1987, and Armstrong and others, 1987) and older faults (Archibald and others, 1984) that may be concealed in the trench also separate the Jumpoff Joe Fault and the St. Mary Fault. Because of the similar structural and stratigraphic contrasts found across these two faults and their approximate alignment, the Jumpoff Joe and St. Mary Faults could very likely represent a single fault or parts of a single fault system. Furthermore, that fault or fault system may be a major Late Proterozoic bounding structure for the Windermere Group sedimentary wedge and may have persisted as a major locus of crustal weakness at least through the late Paleozoic to middle Mesozoic time interval.

Despite possible normal movements in the Late Proterozoic, net strain on the Jumpoff Joe Fault is contractional on the basis of the great dissimilarity of Middle Proterozoic sequences that are juxtaposed by the fault in both the Bonners Ferry and Chewelah quadrangles and by Paleozoic sequences juxtaposed in the Chewelah quadrangle. If extension related to some of the faulting in the late Paleozoic to middle Mesozoic and to metamorphic core complex unroofing in the Eocene caused reactivation of a proto-Jumpoff Joe Fault, then the total amount of contractional strain is even greater than the net strain indicated by differences in lithostratigraphy across the fault. Present understanding of lithofacies distribution in the western Belt basin is not sufficient to estimate the amount of net contractional movement that was required to juxtapose the Deer Trail Group-Belt Supergroup sequences. The multiple-deformation history of the region also compounds the uncertainty of any estimate.

Moyie Fault and structures deforming Belt Supergroup sequences

The extensive 14,000-m-thick (including mafic sills) Clark Fork-Eastport sequence (fig. 1) comprising the Belt Supergroup east of the Purcell Trench and the sequence north of Newport form a normal, or slightly telescoped, progression in lithofacies between themselves and also between them and other Belt sequences east of the Bonners Ferry quadrangle. This normal or slightly telescoped progression in lithofacies extends only to the Jumpoff Joe Fault, where net foreshortening, determined on the basis of lithofacies differences between Belt sequences and the partly correlative Deer Trail Group, is considered to be large.

That part of the Clark Fork-Eastport Belt Supergroup sequence found in the Bonners Ferry quadrangle is disrupted by the Moyie Fault and by a number of smaller faults that are both parallel and divergent to it. Calkins and McDonald (1909) locally applied the name Lenia (presumably an early spelling or misspelling of Leonia) Fault to this structure. Kirkham and Ellis (1926) used the name Moyie-Lenia overthrust fault when its continuity with the Moyie Fault in British Columbia became apparent (Schofield, 1915). Despite the precedence of the name Lenia, we adopt the name Moyie Fault, because of its current widespread usage.

Within the quadrangle, the normally west-dipping Moyie Fault at the surface is nearly vertical and locally is slightly overturned. The hanging wall of the fault consists of east-dipping Prichard Formation, stratigraphically as high as middle Prichard (unit F of Cressman, 1985; Ymp of Finch and Baldwin, 1984). The footwall consists of west-dipping Belt Supergroup rocks as young as Mount Shields Formation and, in a limited area, a fault-bounded slice of Cambrian carbonate rocks. Minimum stratigraphic throw on the Moyie Fault to juxtapose the middle Prichard Formation and Mount Shields Formation, using thickness estimates from east of the quadrangle, is about 8 km. If a 2,000-m-thick section of Bonner Quartzite and Libby Formation found just east of the quadrangle (Harrison and others, 1992) had been present below the Cambrian carbonate rocks, stratigraphic throw would be about 10 km.

Northeastward from the Bonners Ferry quadrangle, movement on the Moyie Fault appears to increase, and southeastward from the quadrangle it appears to decrease. About 45 km northeast of the international boundary, the Moyie Fault is a northwest-dipping, right-oblique reverse fault having a dip separation component of 16 km. Directly southeast of the quadrangle, the fault is interpreted by Harrison and others (1992) and by Harrison and Cressman (1993) to shallow at depth and to be a west-dipping reverse fault, although they present no direct evidence for its direction and amount of dip or for its sense of movement. In a structure cross section 37 km along strike to the southeast, Harrison and others (1992) show the Moyie Fault having a 60° west dip at the surface, shallowing to about 20° at a depth of about 8,200 m. They also show about 3 km of reverse offset, but state that the offset shown includes some back-slip that occurred during a later period of extension. The fault continues southward from there, gradually bending to the west, and ends against the Hope Fault 45 km south of the quadrangle and a few kilometers east of longitude 116°. In this area, juxtaposition of Prichard and Revett Formations by the Moyie Fault, suggests 4 km of dip slip (Fillipone and Yin, 1994).

Despite the interpretation by Harrison and others (1992) and Harrison and Cressman (1993), there is little evidence in the Bonners Ferry quadrangle or directly east of it that the Moyie Fault shallows at depth. Because the dip is nearly vertical at the few localities where the fault is exposed in the Bonners Ferry quadrangle and attitudes of Belt rocks near the fault are also steep, it is not possible to accurately estimate the amount of displacement on the fault other than that it is large. Harrison and Cressman (1993) estimate about 8 km of horizontal shortening across the fault; this estimate translates into about 11 km of displacement on a fault having an average dip of 45°.

Between the Purcell Trench Fault and the Moyie Fault, Belt Supergroup rocks form an east-dipping, essentially homoclinal section and are cut by scattered faults with widely varying strikes. East of the Moyie Fault, the west-dipping homoclinal section of Belt Supergroup rocks represents the west limb of the Sylvanite Anticline, the axis of which lies east of the quadrangle (Harrison and others, 1992). Rocks of this west-dipping homoclinal section east of the fault are cut by about the same concentration of faults as the rocks west of the fault and have about the same diversity in strikes. Stratigraphic throw on these secondary faults is both down-to-the-east and down-to-the-west. Very few of the faults are exposed, so little is known about direction or amount of dips and, consequently, whether most are normal or reverse faults. Some of these faults, particularly those nearest the Purcell Trench, are probably Eocene normal faults related to unroofing of the Priest River complex. However, only the small fault cutting the Cretaceous granodiorite of Copeland, 5 km east of Copeland, and the faults immediately north and immediately east of that fault are considered with confidence to be Eocene.

Most of the faults west of the Moyie Fault and most of those in the north half of the quadrangle east of the Moyie Fault are wholly within the Prichard Formation, and the amount of displacement on them is poorly constrained. Except for the upper part, the internal stratigraphy of the Prichard Formation is extremely monotonous and lacks identifiable markers to document fault offsets. The mafic sills intruding the Prichard Formation are the best references for offsets across these faults, but even the sills are rather undistinctive. In a limited way, they are distinguished from one another by their relative sizes, differentiation, and evidence for intrusion into wet sediment, although each of these characteristics can vary along strike. Identifiable groups of sills are the best references for determining offsets on faults that are restricted wholly to the Prichard Formation. Up-on-the-east S-C fabrics found several places near the southern edge of the quadrangle on faults that are close to, and parallel, the Moyie fault, suggest back-slip.

Age of faulting in the Belt Supergroup rocks east of the Purcell Trench is poorly constrained. East of the Moyie Fault in the Bonners Ferry quadrangle, the concentration and orientations of faults are similar to those mapped by Harrison and others (1992) immediately to the east in the Kalispell 1° x 2° quadrangle. Although they concluded that most thrusting in the western part of the Kalispell quadrangle occurred about 100 Ma, in the eastern part of the Bonners Ferry quadrangle no faults cut any of the approximately 100 Ma plutons or the Triassic or Jurassic monzonite of Wall Mountain except for Eocene faults near the Purcell Trench. Harrison and others (1992) also concluded that a number of the faults that were initially thrust or reverse faults in the Cretaceous backslid during Eocene extension; specifically they include the Moyie Fault as one of these. We found no compelling evidence in the Bonners Ferry quadrangle that would allow quantitative estimates of Eocene backsliding on the Moyie Fault or any other fault, although localized S-C fabrics developed in rocks near the Moyie Fault suggest some backsliding could have occurred.

Priest River complex

The Priest River complex is a large body of predominantly two-mica granitoid rocks that includes lesser amounts of metasedimentary and meta-igneous rocks. It is one of several metamorphic core complexes in northern Washington, northern Idaho, and southern British Columbia. Beginning about 45 km west and southwest of the Bonners Ferry quadrangle, the Priest River complex extends eastward, partly beneath the Newport Fault, emerges on the east side of Priest Lake, and continues for another 33 km to the Purcell Trench (figs. 1 and 2). In a north-south direction, the complex extends from at least the United States-Canada boundary to about latitude 48° N.; the southern limit of the complex is ill-defined and may represent a normal gradational progression from mid-crustal to relatively higher level granitic rocks. The relationship between the

Priest River complex and rocks of the Spokane dome of Cheney (1980), south of the quadrangle, is unclear. Doughty and Price (1999) interpret a combination of geologic mapping, paleobarometric, and isotopic evidence to strongly suggest that the Spokane dome of Cheney (1980) lies structurally above the Priest River complex.

The northern limit of the Priest River complex near the United States-Canada boundary may be a north-plunging domal structure as defined by discontinuous exposures of the monzogranite of Hunt Creek (Kphc) wrapping around the monzogranite of Shorty Peak (Kpsh). Metamorphosed Prichard Formation on the west edge of the Purcell Trench and the mixed granitic and metamorphic rocks in the Lookout Mountain area may also define this domal structure, because most of the metamorphic rocks of Lookout Mountain (Kplm) that enclose the monzogranite of Hunt Creek west of the monzogranite of Shorty Peak are composed of highly metamorphosed Prichard Formation, and because the Kplm unit grades westward into increasingly less metamorphosed Prichard Formation.

As informally used by Miller and others (1999), the Priest River complex approximately conforms to the Priest River crystalline complex defined by Reynolds and others (1981) and Rehrig and others (1987). The Priest River complex is composed of 24 distinct plutonic-metamorphic units, 20 of which are found in the Bonners Ferry quadrangle. Nineteen of these 24 units are predominantly granitoid, interspersed with five irregularly shaped masses of mixed metamorphic and granitic rocks. Individual units of the complex are probably not distinct sequentially emplaced plutons, but rather, together represent one or more inhomogeneous, composite intrusive masses of predominantly muscovite-biotite granitic rocks that are variably intermixed with metamorphic rocks. In the Bonners Ferry quadrangle, the metamorphic rocks are both metasedimentary and meta-igneous, probably derived mostly from the Belt Supergroup. About 30 km south of the quadrangle, Evans and Fischer (1986) describe a pre-Belt 1,578-Ma orthogneiss, and in the same area, Doughty and others (1998) describe a 2,651 Ma migmatitic gneiss; both units are within the Priest River complex. Protoliths of the Priest River complex thus range in age from Archean to Cretaceous, and following amalgmation of the constituent parts of the complex, are variably overprinted by Cretaceous(?) and Eocene deformational fabrics.

In the Chewelah quadrangle to the southwest, the western side of the complex is made up of two-mica granitic rocks of the Phillips Lake Granodiorite, which intrude the Belt Supergroup and include abundant highly recrystallized metasedimentary rocks derived from the Belt units. All of the granitic rocks in the complex, except for the Phillips Lake Granodiorite, yield Eocene potassium-argon ages, even though all probably were emplaced in the Mesozoic.

The east side of the Priest River complex is interpreted to be an east-dipping fault concealed beneath thick Quaternary deposits in the Purcell Trench. Reynolds and others (1981) and Rehrig and others (1987) consider the fault to be a through-going detachment fault. Doughty and Price (2000) consider it to be a normal fault extending from north of the United States-Canada border to south of Spokane but having an approximately 16 km gap which extends from about 4 km north of the southern edge of the quadrangle to about 12 km south of the quadrangle.

The northwest boundary of the complex in the Bonners Ferry quadrangle appears to be intrusive, but much of the two-mica rocks within a kilometer of the contact are variably mylonitic, and the host Prichard Formation is highly deformed. This contact may have been a fault when the complex was at mid-crustal levels, but the deformed rocks have been highly recrystallized and show none of the brittle deformation found on the east side of the complex and along the Newport Fault.

Purcell Trench Fault

The Clark Fork-Eastport sequence of the Belt Supergroup is sharply bounded on the west and juxtaposed against the Priest River complex by the Purcell Trench Fault (fig. 1), which lies beneath Quaternary deposits in the Purcell Trench. The Purcell Trench Fault is nowhere exposed in the Bonners Ferry quadrangle but is inferred on the basis of the metamorphic and deformational contrast across the Purcell Trench. On the west side of the trench, coarse-grained quartz-feldspar-biotite-muscovite schist (Yppm), locally containing alumnosilicate minerals, and numerous amphibolite bodies derived from the Middle Proterozoic Prichard Formation and the mafic sills that intrude it form a kilometers-wide band from the United States-Canada boundary southward for a distance of about 40 km. Large clots of fine-grained muscovite in much of the schist probably represent retrograded alumnosilicate minerals. Numerous pegmatite, alaskite, and fine-grained two-mica bodies intrude the schist. All of this unit, including some of the granitic rocks, is tightly folded and faulted, and, except very locally, all sedimentary features in the rocks are destroyed. Directly across the trench, on the east side, Prichard Formation in which all sedimentary structures are preserved is intruded by thick mafic sills, shows only low greenschist burial metamorphism, is mildly or not at all folded, and is cut by relatively few faults. In addition, Cretaceous granitic rocks on the east side of the trench, with few exceptions, yield Cretaceous potassium-argon ages, but on the west side the rocks yield Eocene cooling ages (Miller and Engels, 1975).

The metamorphic and deformational contrast across the Purcell Trench is present from at least the United States-Canada boundary to a point about 3 km north of the town of Elmira, where the two-mica granitic rocks, the metamorphic contrast, and to a lesser degree, the deformational conditions found on the west side of the trench cross to the east side for a distance of about 16 km along the trench. Eastward from the trench along this 16 km stretch, the two-mica granitic rocks and the anomalous metamorphic and deformational conditions gradually diminish and grade into conditions characteristic of the east side of the trench; no fault east of the trench separates the higher rank rocks from the essentially unmetamorphosed rocks that are characteristic of the east side. On the basis chiefly of comparison of metamorphic grade and paleobarometry across the trench in this interval, Doughty and Price (2000) conclude that this 16 km segment is not faulted. Alternatively, these higher rank rocks east of the inferred position of the Purcell Trench Fault may represent a segment of the uppermost part of the Priest River complex which was clipped off by the Purcell Trench Fault and downdropped with the rest of the relatively unmetamorphosed Belt Supergroup rocks above the proto-complex prior to general Eocene unroofing in the region.

Newport Fault

The Newport Fault has a 200-km-long, U-shaped trace; from the Bonners Ferry quadrangle, it continues southward, bending westward just north of the Pend Oreille River (fig. 1). West of Newport, Washington, the fault turns north again on the west side of the Pend Oreille River and continues almost to the United States-Canada boundary (Miller and Engels, 1975; Miller, 1994). It is a spoon-shaped, shallowly dipping listric normal or detachment fault (Harms and Price, 1992) that appears to steepen northward along both limbs of the U-shaped trace. Along both limbs, from about the point where the Jumpoff Joe Fault intersects it, the Newport Fault is more like a conventional normal fault than a listric normal or detachment fault. The Newport Fault juxtaposes hanging-wall, low-grade rocks of the Belt Supergroup and the intermediate- to shallow-depth plutonic rocks that intrude them against an infrastructure of two-mica granitic rocks and coarsely recrystallized Belt Supergroup rocks of the Priest River complex.

A zone of chlorite breccia and chloritized, brittlely deformed rocks that ranges from about 150 to 250 m thick marks the upper part of the footwall of the fault zone. This brittle deformation overprints ductilely deformed mylonite that extends variable distances away from the fault. Thinner, discontinuous zones of chlorite breccia up to 120 m wide are found in the footwall as far as 6 km from the main trace. Harms and Price (1992) mention that the mylonite ranges from 15 to 500 m thick but is best developed beneath the southern and eastern parts of the fault. Tectonic transport direction indicated by kinematic structures in these mylonitic rocks is consistently top to the east, except within a few hundred meters of the Newport Fault, where they are consistently top toward the fault trace. This top-to-the-east zone of mylonite may be part of a wide zone of mylonitized rock (McCarthy and others, 1993) found south of the quadrangle (fig. 1), which appears to be continuous with extensively mylonitized rock (Rhodes and Hyndman, 1984) associated with the Spokane dome of Cheney (1980) further south.

Harms and Price (1992) documented convincingly that the Newport Fault and related bounding structures were produced by extension and calculated that between 12 and 38 km of lateral extension occurred on the eastern limb of the Newport Fault on the basis of separation of the Newport and Clark Fork-Eastport Belt Supergroup sequences (fig. 1). The lithostratigraphic differences between these two sequences, however, is great enough to indicate that they probably are not offset parts of a once continuous sequence but were slightly telescoped by late Paleozoic to middle Mesozoic thrust faults, which presumably were subsequently obliterated by Cretaceous granitic plutons. It is not possible to estimate the amount of telescoping that occurred, but it probably exceeded the amount of extension in the Eocene. Lithostratigraphic differences of similar magnitude between the Newport and Chewelah Belt Supergroup sequences (fig. 1) suggest that pre-extension telescoping also may have occurred west of the Newport Fault.

Eocene normal faults

Eocene normal faults, some of which cut Cretaceous plutons, are associated with the extensional event responsible for unroofing the Priest River complex and other metamorphic core complexes in the region. West of the Bonners Ferry quadrangle, nearly all occurrences of Eocene sedimentary and volcanic strata are bounded on at least one side by faults of this group. These faults are fairly numerous in the Colville and Pend Oreille River valleys west of the quadrangle, but due to the absence of Eocene volcanic and sedimentary units in the Bonners Ferry quadrangle they are not as easily identified here. About 8 km south of the quadrangle, the Sandpoint Conglomerate forms scattered outcrops within the Purcell Trench. Harrison and others (1972; see also, Harrison and Schmidt, 1971) considered the Sandpoint Conglomerate to be Cretaceous in age on the basis of the lack of Cretaceous granitic clasts in the unit. Later work (Doughty and Price, 2000) showed the Sandpoint Conglomerate to be Eocene in age and to be cut by Eocene faults.

Eocene faults are probably present beneath the Quaternary sediments in the Purcell Trench, and some of the faults cutting the Belt Supergroup east of the trench are probably Eocene. From the Purcell Trench westward, rocks and older faults are broken by a number of Eocene normal faults. Many of these faults are mostly covered by surficial material in the major river valleys but, where exposed, appear to be relatively steeply dipping, generally toward the Purcell Trench. Some have stratigraphic separations greater than 3,000 m. All these faults that cut granitic rocks have developed highly chloritized breccia zones.

Along the west side of the Purcell Trench abundant, thin, discontinuous breccia zones in the metamorphic and granitic units, some of which are highly chloritized, suggest that Eocene brittle deformation is probably more extensive than shown on the geologic map. In this area, these thin, discontinuous breccia zones are distributed across an irregular-width band parallel to the Purcell Trench, which averages several kilometers in width.

INTRUSIVE EPISODES

The oldest magmatic activity in the map area was intrusion of tholeiitic magma into sediments of the Prichard Formation during its deposition at about 1,468 Ma, on the basis of dates obtained on comparable rocks elsewhere (Anderson and Davis, 1995; Sears and others, 1998). Mafic sills at higher stratigraphic levels may be related to extrusion of Purcell lavas to the north and east. Zoned zircons from a porphyritic rhyolite or quartz latite flow in the lower part of the upper unit of Purcell Lava between the Snowslip and Shepard Formations about 40 km east of the quadrangle yielded a concordia age of 1,443 ±7 Ma (Evans and others, 2000).

Granitic rocks within the quadrangle were intruded in the Mesozoic, probably Triassic or Jurassic, and in the Jurassic, Cretaceous, and Eocene. The alkalic monzonite of Wall Mountain and monzonite of Long Canyon are the only plutons of probable Triassic or Jurassic age in the Bonners Ferry quadrangle, and the tonalite and trondhjemite of Continental Mountain are the only Jurassic plutons. Tentative age assignment of the two alkalic bodies is based primarily on compositional similarities to Triassic or Early Jurassic plutons in other parts of the Cordillera (Miller, 1978), although there are also rare Cretaceous plutons of this age. Both the Wall Mountain and Long Canyon bodies are mineralogically and chemically distinct from all Cretaceous and Tertiary plutons in the quadrangle; they have much lower quartz content, higher hornblende to biotite ratios, lower SiO_2, and higher total alkali content. Comparison of the Continental Mountain bodies with younger rocks is complicated by metamorphism of the former.

By far the largest volume of granitic rocks was emplaced in the Cretaceous. These rocks include two petrogenetically distinct types: hornblende-biotite granitoids and muscovite-biotite (two-mica) granitoids. Within the resolution of isotopic dating, both types were intruded in the same time interval (Miller and Engels, 1975; Whitehouse and others, 1992). Volumetrically, most of the muscovite-biotite units are part of the Priest River complex. Exposures of crosscutting relations between plutons, even outside the Priest River complex, are generally not adequate to establish the sequential order of emplacement for most granitoids, but the cross-cutting relations are sufficient to suggest that emplacement of the two petrogenetically distinct types probably overlapped in time.

Outside of the Priest River complex, Cretaceous plutons ranging in composition from granodiorite to monzogranite are scattered throughout most of the Bonners Ferry quadrangle. They form some of the largest intrusive bodies in the area, such as the granodiorite of Reeder Creek west of Priest Lake and the granodiorite of Copeland east of Copeland (fig. 1). Relative ages of these Cretaceous granitic units are very poorly known primarily because definitive intrusive relations are rarely exposed and because many of the granitic units are isolated and not in contact with any other pluton. Almost all isotopic ages that have been determined for these rocks fall between roughly 90 and 100 Ma (see Description of Map Units), and within the resolution of the various dating methods, the units are nearly the same age. Because of this, chiefly to establish a sequence in the Description of Map Units section, most of the Cretaceous units are divided into five informal petrogenetic groups: (1) highly evolved leucocratic rocks, (2) highly evolved two-mica plutonic rocks, (3) rocks containing biotite as the characterizing mineral, (4) rocks containing hornblende and biotite as characterizing minerals, and (5) mafic-rich, hornblende-biotite plutonic rocks.

Co-existing mineral pairs from most plutons in the hanging wall of the Newport Fault and from plutons east of the Purcell Trench yield concordant or near-concordant potassium-argon ages, most of which are considered to approximate emplacement ages. Within the Priest River complex, potassium-argon dating yields cooling ages that range from near-emplacement ages on the west side of the complex (west of the Bonners Ferry quadrangle) to the age of unroofing in parts of the complex between the Newport Fault and Purcell Trench (Miller and Engels, 1975; Harms and Price, 1992).

Eocene intrusions are restricted to the small stock on Trapper Mountain and to numerous hypabyssal dikes that are too small to show at the scale of the map.

DESCRIPTION OF MAP UNITS

Qag **Glacial and alluvial deposits (Quaternary)**—Till from continental glaciation and all alluvial material in modern drainages. Generally pale-tan or pale-gray unconsolidated boulders, gravel, sand, and silt. Some alluvial deposits locally reflect colors of bedrock source. Semi-consolidated to consolidated clay, silty clay, and sandy clay. Clay-bearing parts are well-bedded to indistinctly bedded. Coarser parts are well bedded, indistinctly bedded, and massive; some sand and gravel deposits are well bedded, displaying large- and small-scale crossbedding. Clasts in alluvial deposits reflect local bedrock sources. Clasts in glacial deposits are mostly from bedrock units recognized in quadrangle but also include exotic metamorphic, granitic, and volcanic clasts. Clasts range from subrounded to well rounded; nearly spherical cobble-sized clasts are abundant locally. Flattened clasts commonly are imbricated. In general, degree of rounding does not appear to correlate with clast size. Thickness of glacial and alluvial deposits is highly variable, ranging from thin, discontinuous deposits near bedrock or in steep canyons to possibly more than 100 m in major river valleys

Qls **Landslide deposits (Quaternary)**—Unconsolidated rubble resulting from landslides and slips. Identified chiefly by geomorphic form on aerial photographs

Ql **Glacial-lacustrine deposits (Quaternary)**—Silt, sand, gravel, and probably clay deposited in glacial and possibly post-glacial lakes occupying Kootenai River valley. Most of unit is poorly indurated, fine-grained silt that is finely to massively bedded. Variably shaped concretions common locally. Around margins, unit contains thick wedges of gravel and sand that pinch out over short distances. Some wedges contain abundant, unsorted boulders. Boulders up to several meters across, presumably ice rafted, also found in fine-grained silt away from margins of unit

Tcb **Chlorite breccia and cataclastic rocks associated with the Newport Fault Zone (Eocene)**—Green or gray, finely comminuted cataclastic rocks and highly fractured and chloritized rocks in footwall of Newport Fault Zone. Near fault plane, includes nearly aphanitic chlorite breccia containing millimeter- to centimeter-long, angular, internally fractured, matrix-supported feldspar fragments. Away from fault plane, grades progressively into less-fractured rock in which all mafic minerals are chloritized and fracture planes are chlorite coated. Best developed in southern part of fault zone where unit is between 50 and 100 m thick

Ttp **Quartz monzonite of Trapper Peak (Eocene)**—Quartz monzonite to monzonite. Forms single stock centering on Trapper Peak 11 km north of Upper Priest Lake (fig. 2). Chilled, fine-grained margin ranging from 20 to 70 m in width contains 2- to 5-mm-long olivine, hypersthene, clinopyroxene, hornblende, and biotite phenocrysts in fine-grained matrix of plagioclase, potassium feldspar, quartz, hornblende, and biotite. Interior is non-porphyritic, medium grained and contains clinopyroxene, hornblende, biotite, only sparse hypersthene, and no olivine. Gradation from marginal to interior phase only a few meters wide. Age assignment based on mineralogical similarities to other Eocene intrusive rocks and absence of fabric found in surrounding Priest River complex (fig. 1). Appears to cut Newport Fault

Granitic and metamorphic rocks of the Priest River complex

Priest River complex—Consists of predominantly muscovite-biotite granitoid rocks and lesser amounts of metasedimentary and meta-igneous rocks; metamorphic rocks derived all or partly from Belt Supergroup. East part of complex lies between Purcell Trench and east arm of Newport Fault, central part inferred to extend under spoon shaped Newport Fault, and west part continues for as far as 20 km west of west arm of Newport Fault (fig. 1). East boundary in Purcell Trench may be a detachment fault. Northern and most of western boundary appear to be intrusive. Southern boundary is ill-defined chiefly because relation of Priest River complex to Spokane dome of Cheney (1980), which lies south of quadrangle, is unclear. Granitoid bodies making up complex differ from one another in texture, mineralogy, and to lesser degree, bulk composition. In any particular unit, dikes, pods, or small bodies of other units may occur as small intrusions or inclusions. Nearly all units have wide, gradational boundaries and are probably not distinct sequentially emplaced plutons, but rather, collectively represent a single inhomogeneous, composite intrusive mass. Cross-cutting relations in Priest River complex are ambiguous due to composite nature of complex and are of little value to determine relative ages of constituent units. Units are therefore described in order, roughly from west to east. All granitic units of complex are probably Cretaceous, except for two older(?) included bodies, Mesozoic monzonite of Long Canyon (Mzpl), and Cretaceous monzogranite of Hunt Creek (Kphc). Priest River complex is both a structure and a collection of rocks. Age of structure is Eocene; age of rocks range at least from Cretaceous to Middle Proterozoic, and possibly older. Although no two-mica body in complex has been identified as Eocene in age, that possibility cannot be excluded. Except along northwestern margin, nearly all granitic rocks in complex give biotite potassium-argon cooling ages of roughly 50 Ma. Complex includes 20 separately mapped units

Kptc **Granodiorite of Trapper Creek (Cretaceous)**—Medium-grained muscovite-biotite granodiorite. Forms single body north and east of Upper Priest Lake; west side of unit faulted away by Newport Fault. Rock is essentially nonporphyritic but locally contains poorly formed 2 cm-long phenocrysts. Plagioclase composition averages an_{30}. Potassium feldspar is microcline and is irregularly distributed in rock with respect to amount and grain-size; most feldspar forms anhedral, locally poikilitic, intergranular fillings. Biotite is only mafic mineral. Color index averages 9. Biotite to muscovite ratio varies widely, averages about 10:1; higher than most rocks of Priest River complex. Accessory minerals include zircon, apatite, and epidote, much of which has allanite cores. Texture ranges from hypidiomorphic-granular to seriate. Unit includes abundant pegmatite and leucocratic dike rocks, but otherwise it is slightly more uniform than most units of Priest River complex

Kplm **Mixed granitic and metamorphic rocks of Lookout Mountain (Cretaceous)**—Extremely heterogeneous unit made up of several two-mica rock types that intrude and are mixed with metamorphic rocks probably derived from Middle Proterozoic Belt Supergroup. Forms large, irregular, partly arcuate mass northeast of Upper Priest Lake and extending to United States-Canada boundary. Unit is essentially wide gradation zone between granitic units bounding it; contains very high proportion of included material. In parts of unit as much as 1 km^2 in area, granitic rock appears relatively uniform with respect to texture and mineralogy, but most of unit is heterogeneous on scale of square meters. Granitic rocks include rocks characteristic of granodiorite of Caribou Creek (Kpcc), monzogranite of Klootch Mountain (Kpkm), mafic granodiorite of Lucky Creek (Kplc), and granodiorite of Trapper Creek (Kptc), but much of unit is dikes, pods, and irregularly shaped bodies of alaskite, pegmatite, and fine-grained, equigranular biotite and two-mica granitic rock. Composition of pegmatite and fine-grained equigranular granitic rock ranges from granite to tonalite in individual outcrops. Rocks of granitic, tonalitic, and all compositional gradations between are nearly identical in appearance. Metamorphic rocks are chiefly plagioclase-muscovite-biotite-quartz schist, amphibolite, and minor gneissic monzogranite. Schist and amphibolite are probably derived from Middle Proterozoic Prichard Formation and mafic sills in Prichard Formation, respectively. Concentration of metamorphic rocks greatest near contact with Prichard Formation where metamorphic rocks form irregularly shaped masses from a few centimeters to 1 km in length; in most of unit metamorphic rocks form mainly thin seams and schlieren. Southeast of Trapper Peak, much of metamorphic rock in unit is calc-silicate rock, possibly derived from Middle Proterozoic Wallace or Shepard Formations

Kpgb **Garnet-bearing granodiorite (Cretaceous)**—Medium-grained two-mica granodiorite, ranging to tonalite. Forms single, small body 9 km north of Upper Priest Lake. Characterized by sparse but ubiquitous pale-tan garnet. Average plagioclase composition is an_{25}, slightly more sodic than most rocks of Priest River complex. Potassium feldspar is microcline, which is interstitial to all other minerals. Biotite is only mafic mineral; color index averages 8. Biotite to muscovite ratio about 5:1. Contains abundant epidote and clinozoisite, but unlike most other units of Priest River complex, allanite is almost absent. Accessory minerals include zircon and apatite but unit has conspicuous absence of opaque minerals. Contains anhedral and embayed sphene, unusual for rocks of Priest River complex, which normally are deficient in titanium. Sphene, garnet, abundant epidote, and clinozoisite could result from incompletely mixed anatectic melt derived from sedimentary rocks and mafic sills of Middle Proterozoic Prichard Formation. Texture is seriate for most of pluton; foliate near margins

Kpcc **Granodiorite of Caribou Creek (Cretaceous)**—Medium- to coarse-grained muscovite-biotite granodiorite, but ranges from tonalite to monzogranite. Forms large oval body 2 km northeast of Upper Priest Lake. Unit characterized by extreme variation in potassium feldspar content; ranges from 3 to 40 percent (fig. 3). Plagioclase composition averages an_{30}. Potassium feldspar is microcline. Biotite is only mafic mineral; color index averages 6, ranging from 4 to 10. Biotite to muscovite ratio averages 1:3, but ranges to rocks that contain no muscovite. Accessory minerals include apatite, zircon, opaque minerals, and epidote having cores of allanite. Texture of most rocks is seriate and hypidiomorphic-granular. Locally unit contains sparse, poorly formed phenocrysts to 3 cm in length. Despite compositional variations, unit is much more uniform in appearance than most units of Priest River complex; however, there are discrete areas of pronounced textural and compositional inhomogeneity, especially in northwestern part

Kpml **Mafic granodiorite of Marsh Lake (Cretaceous)**—Medium- and fine-grained biotite granodiorite; ranges to tonalite. Forms two small, roughly aligned, elongate bodies 10 km northeast of Upper Priest Lake. Unit is characterized by euhedral allanite with epidote overgrowths and average color index of 15, which is very high for units of Priest River complex. Average plagioclase composition an_{30}; crystals relatively unzoned. Potassium feldspar is microcline; concentration ranges widely, even on outcrop scale. Biotite is only mafic mineral. Locally, rock contains trace amounts of muscovite, which is probably secondary. Accessory minerals include zircon, apatite, opaque minerals, and locally sparse, anhedral, embayed crystals of sphene. Unusual presence of sphene, similar to garnet-bearing granodiorite (Kpgb) and granodiorite of Search Lake (Kpsl). Anomalous sphene appears to be characteristic of units intruding large mass of Middle Proterozoic Prichard Formation to northwest. Much of rock has subtle foliation and lineation similar to incipient mylonitic stretching lineation

Kpsl **Granodiorite of Search Lake (Cretaceous)**—Medium- and locally coarse-grained muscovite-biotite granodiorite (fig. 3). Forms single, tear-drop shaped pluton 11 km northeast of Upper Priest Lake. Average plagioclase composition an_{35}. Most potassium feldspar is microcline but some appears to be orthoclase; many grains contain abundant included plagioclase crystals. Biotite is only mafic mineral; average color index is 11. Biotite to muscovite ratio variable but averages 8:1. Abundant allanite, commonly euhedral, some having rims of epidote. Zircon and opaque minerals are ubiquitous but dearth of apatite is conspicuous. Rocks contain anhedral, embayed crystals of sphene. Texture is hypidiomorphic-granular to seriate; slightly foliate in northeast part. Unit is more uniform in composition and contains lower proportion of leucocratic dike rocks than most units of Priest River complex. Castor and others (1981) report occurrence of uranium-bearing mineral (brannerite) in northwestern part of pluton

Kplc **Mafic granodiorite of Lucky Creek (Cretaceous)**—Medium- to coarse-grained tonalite to monzogranite; average is granodiorite but large parts of unit are represented by compositional extremes (fig. 3). Forms single body east of Upper Priest Lake. Unit is heterogeneous mixture of granitic types that grade from one to another over distances of centimeters to tens of meters. Distinguished by heterogeneity, wide compositional range, and variable but relatively high color index that ranges from 5 to 20, averages 13. Plagioclase composition ranges from an_{24} to an_{32}; potassium feldspar is orthoclase with patches of microcline. Concentration of potassium feldspar in unit is extremely variable on all scales. Biotite is only mafic mineral. Trace amount of muscovite in much of unit. Has poorly developed foliation in places. Contains large irregularly shaped mafic inclusions, many with diffuse borders. Texture, composition, and concentration of inclusions extremely variable throughout body

Kpkm **Monzogranite of Klootch Mountain (Cretaceous)**—Medium- to coarse-grained muscovite-biotite monzogranite; ranges to granodiorite (fig. 3). East and northeast of Priest Lake forms very large pluton, which has elongate lobe that reaches nearly to United States-Canada boundary. Distinguished from many other units of Priest River complex by relatively abundant, well-formed 2.5- to 4-cm-long potassium feldspar megacrysts. Plagioclase composition averages between an_{25} and an_{30}. Potassium feldspar is microperthitic orthoclase, some having patches of microcline. Biotite is only mafic mineral; average color index is 6. Biotite to muscovite ratio averages 3:1. Micas are about same size as other minerals in rock; in most units of Priest River complex micas are distinctly smaller. Muscovite found locally as 1-cm-wide poikilitic crystals. Accessory minerals include apatite, zircon, opaque minerals, and moderately abundant epidote having cores of allanite. Groundmass texture is hypidiomorphic-granular to seriate. Composition and texture very uniform compared to other units of Priest River complex. Contains abundant leucocratic dikes ranging from pegmatite to alaskite, but concentration of dikes is lower than in most Priest River complex units. Unit has subtle foliation and lineation in southern part but minerals have no primary preferred orientation in most of unit. Locally foliate and shows ductile grain-size reduction within 2 km of Newport Fault

Kph **Two-mica granitic rocks of Horton Creek (Cretaceous)**—Chiefly leucocratic, muscovite-biotite monzogranite but much of unit is granodiorite. Forms single triangular body east of Priest Lake. Unit includes abundant pegmatite, alaskite and leucocratic dikes, probably over 15 percent by volume. Plagioclase composition ranges from intermediate oligoclase to calcic andesine. Potassium feldspar is orthoclase, much of it cream colored. Biotite is only mafic mineral; color index averages about 6 but ranges from 2 to 12 even in individual outcrops. Muscovite is extremely abundant in some parts of unit, and average grain size of muscovite is consistently larger than in most units of Priest River complex. Grain size ranges from fine to coarse; texture ranges from equigranular to seriate, but most rocks are foliate or lineate due chiefly to semi-ductile grain-size reduction and proximity to Newport Fault. Compositionally and texturally unit is extremely heterogeneous; very similar to mixed granitic rocks of Camels Prairie (Kpcp), but lacks metamorphic rocks included in that unit

Kpcb **Mafic granodiorite of Cavanaugh Bay (Cretaceous)**—Biotite granodiorite and probably some tonalite. Forms single elongate body on east side of Priest Lake near southern end of quadrangle. Heterogeneous with respect to texture and composition, especially color index, but not as much so as some units of Priest River complex. Plagioclase composition averages an_{30} but is highly variable. Potassium feldspar is orthoclase, much of it forming 1.5- to 4-cm-long megacrysts, but parts of unit are devoid of megacrysts. Biotite is only mafic mineral; average color index 14, but ranges to over 20 in as much as 30 percent of unit. Much more mafic than most units of Priest River complex. Muscovite sparse and local. In western half of unit, many grains of both feldspars are rounded and have fine-grained trains of ductilely and brittlely mixed quartz and feldspar. Rocks in this part of unit are lineate and foliate. Fine-grained gray dikes and coarse pegmatite dikes common throughout unit. In western part of unit, most dikes have tectonic fabric of host rock, but some appear to cross-cut fabric

Kpcp **Mixed granitic rocks of Camels Prairie (Cretaceous)**—Mixed leucocratic two-mica granitoid rocks, numerous dikes, and lesser metamorphic rocks. Forms irregularly shaped body in south-central part of Priest River complex (fig. 1). Basically same assemblage of granitic rocks as found in mixed granitic and metamorphic rocks of Soldier Creek unit (Kpms), but Camels Prairie unit consistently contains less than 10 percent metamorphic rocks. Most abundant granitic rock in unit is even-grained two-mica monzogranite, but dikes, pods, and irregular shaped masses of pegmatite and alaskite up to 1 km^2 in area are extremely abundant throughout. Plagioclase composition averages calcic oligoclase, but varies widely; potassium feldspar is both orthoclase and microcline. Biotite is only mafic mineral, but most granitic rocks also contain muscovite. Color index ranges from 1 to about 15; average estimated to be in lower third of that range. Accessory minerals include epidote, allanite, opaque minerals, zircon, apatite, and locally garnet and tourmaline. In much of unit, both color index and texture are highly variable over distances of a few meters but in some parts, such as southwest of Dodge Peak, these features are relatively uniform. Equigranular and seriate are most common textures, but irregular primary foliation is discontinuously and sparsely developed in some parts of unit. Paucity of attitudes is function of both sparse foliation development and widely spaced observations. Most metamorphic rocks are amphibolite and gneiss; unit contains only minor schist. Proportion of metamorphic rocks progressively increases towards mixed granitic and metamorphic rocks of Soldier Creek unit (Kpms) and progressively decreases northeastward

Kpms **Mixed granitic and metamorphic rocks of Soldier Creek (Cretaceous)**—Leucocratic two-mica granitoid rocks, schist, amphibolite, and minor gneiss. Found along southern boundary of quadrangle on both sides of Priest River complex; unit is widespread south of quadrangle (Miller and others, 1999). Granitic rocks range in composition from tonalite to monzogranite; most fall towards alkalic end of that range. About 55 to 75 percent of unit is extremely heterogeneous granitic rocks essentially same as those in mixed granitic rocks of Camels Prairie unit (Kpcp). Similarity close enough that description of granitic rocks in Camels Prairie unit serves for this unit also. Mixed granitic and metamorphic rocks of Soldier Creek differs from Camels Prairie unit chiefly in proportion and type of metamorphic rock. Metamorphic rocks in Soldier Creek unit typically form over 25 percent of unit and consist mainly of schist; amphibolite and gneiss are subordinate. They occur mainly as screens or irregularly shaped bodies from a few ten to a few thousand meters in length. Schist is muscovite-biotite-plagioclase-quartz schist, commonly containing sillimanite or locally andalusite. Amphibolite is interlayered with metasedimentary rocks and much is garnet bearing. Pegmatite and alaskite dikes cut nearly all metamorphic bodies regardless of size. Ratio of metamorphic to granitic rock varies greatly over short distances. Most metamorphic rocks are probably derived from Middle Proterozoic Prichard Formation and mafic sills in that unit

Kpsh **Monzogranite of Shorty Peak (Cretaceous)**—Muscovite-biotite monzogranite to granodiorite; average composition is monzogranite (fig. 3). Forms large, elongate body in north-central part of Priest River complex. Plagioclase composition averages calcic oligoclase. Much of body characterized by 1- to 2-cm-wide, equant potassium feldspar megacrysts. Both megacrystic and groundmass potassium feldspar are microperthitic orthoclase containing patches of microcline. Biotite is only mafic mineral; color index averages 10, but varies widely. Muscovite to biotite ratio averages 2:5. Both micas form thin 1 to 2 mm wide flakes disseminated through groundmass; size of micas is noticeably smaller than other groundmass minerals. Accessory minerals include epidote, allanite, opaque minerals, zircon, and apatite. Unit is predominantly medium grained, but ranges from fine to coarse grained over short distances. Most of unit is structureless, hypidiomorphic-granular to seriate, but contains subtle to moderately well-developed foliation in some parts. Texture and composition are uniform over large areas but also variable over large areas. Localized heterogeneity results from differences in grain size, concentration of megacrysts, and development of primary and secondary foliation. Most rocks in unit are nonfoliate, and in a few areas, up to several square kilometers, coarser grained rocks contain no phenocrysts

Kpbc **Mixed two-mica rocks of Ball Creek (Cretaceous)**—Monzogranite to tonalite; mostly muscovite-biotite granodiorite (fig. 3). Forms wide-spread, elongate, but irregularly shaped body in eastern part of Priest River complex. More texturally and compositionally heterogeneous than most units of complex, but more uniform than mixed granitic rocks of Camels Prairie (Kpcp) and mixed granitic and metamorphic rocks of Soldier Creek (Kpms). Average plagioclase composition is calcic oligoclase. Most potassium feldspar is microperthitic orthoclase containing patches of microcline, but some rocks contain only microcline. Biotite is only mafic mineral; most rocks in unit have color index near 7, rarely greater than 10. Narrow range of color index for otherwise heterogeneous unit unusual in Priest River complex. Muscovite to biotite ratio ranges from about 1:10 to 1:1, but muscovite is conspicuous in nearly all rocks. In parts of unit muscovite occurs as poikilitic megacrysts 1 to 1.5 cm across, similar to that in parts of monzogranite of Klootch Mountain (Kpkm). Accessory minerals include apatite, zircon, allanite, opaque minerals, and locally garnet. Trace amounts of epidote in eastern part, increasing towards contact with Granodiorite of Falls Creek (Kpfc). Most rocks in unit are medium to coarse grained. Nonporphyritic, except for widely spaced areas having poorly formed 1.5-cm-long potassium feldspar phenocrysts and in northern part of unit, which contains well-formed 3-cm-long potassium feldspar phenocrysts. Groundmass texture ranges from seriate to even grained. Irregular-shaped, fine-grained pods and bodies of compositionally diverse rock from centimeters to tens of meters in length are found throughout unit. Dikes and pods of alaskite and pegmatite are common, especially in central and southern parts of unit. Contacts with bounding units gradational over zone averaging 300 m wide

Kpfc **Granodiorite of Falls Creek (Cretaceous)**—Chiefly granodiorite, but grading to monzogranite in western part and tonalite in eastern part. Forms north-south-elongate body in eastern part of Priest River complex southwest of Bonners Ferry. Plagioclase averages sodic andesine. Potassium feldspar is microperthitic orthoclase in southern part of unit and microcline in northern part. Color index averages 10. Biotite is only mafic mineral. Minor muscovite in western part of unit; probably primary. Accessory minerals include epidote, allanite, apatite, zircon, and opaque minerals. Trace amounts of epidote in western part; epidote increases eastward toward contact with tonalite of Snow Peak (Kpsp). Medium to coarse grained; generally seriate. Texture and grain size more uniform than in mixed units to west, more variable than in tonalite of Snow Peak (Kpsp) to east. Unit contains very abundant fine- to coarse-grained leucocratic dikes and pods. Composition, texture, and concentration of included leucocratic rocks vary greatly over short distances in much of unit. Grades westward into mixed two-mica rocks of Ball Creek in northern part of unit. Contact with mixed granitic rocks of Camels Prairie in southern part appears to be a fault

Kpsp **Tonalite of Snow Peak (Cretaceous)**—Tonalite, ranging to granodiorite in westernmost part of unit. Forms north-south-elongate body in eastern part of Priest River complex west of Bonners Ferry. Unit is characterized by abundant pale-green epidote with allanite cores, easily seen in nearly all exposures, and by large, pale, lavender-gray quartz. Average plagioclase composition is intermediate andesine. Contains almost no potassium feldspar in most of unit. Quartz commonly elongated into crude, rod-shaped grains up to 1.5 cm long. Biotite is only mafic mineral; color index higher than most units in complex, ranges from 11 to 17. Muscovite, generally absent, is probably secondary where it is found sparsely and irregularly in westernmost part of unit. Tonalite is medium and coarse grained and seriate in much of unit. Subtle to prominent foliation and lineation are irregularly developed but generally best developed in eastern part. Contains abundant irregularly shaped mafic inclusions ranging from 1 cm to tens of meters throughout unit. Composition and texture are much more uniform than in most Priest River complex units but are variable around concentrations of mafic inclusions and are increasingly variable westward in unit

Kpdc **Granitic and metamorphic rocks, undivided (Cretaceous)**—Mafic to leucocratic granitic rocks with screens and inclusions of metamorphic rocks, chiefly schist.

Mapped only west of Deep Creek (fig. 2), where rocks show extreme variations in composition, grain size, and texture, and all contain epidote. Unlike most other units of Priest River complex, some rocks in this area contain hornblende and sphene and locally are highly porphyritic. May include some rocks of granodiorite of Kelly Pass (Kkp) and granodiorite of Bonners Ferry (Kbf), which are east of, and not part of, Priest River complex

Kphc **Monzogranite of Hunt Creek (Cretaceous)**—Biotite granodiorite to monzogranite and gneissic granodiorite to monzogranite (fig. 3). Forms discontinuous, elongate mass from north edge of quadrangle, southward to Cavanaugh Bay on Priest Lake. Characterized by 2- to 10-cm-long potassium feldspar phenocrysts. Potassium feldspar is microcline and microperthite containing patches of microcline. Almost all potassium feldspar is in phenocrysts; unit contains very little in groundmass. Plagioclase composition averages an_{22}. Biotite is sole mafic mineral and commonly occurs as ragged-edged grains or groups of grains that may be result of structural disaggregation of large single grains. Ragged-edged biotite is interleaved with very fine grained muscovite and opaque minerals . Color index is as high as 20 in northern part of body, which becomes progressively more leucocratic southward; in southern part, rock has color index between 8 and 14. Sphene is most abundant accessory mineral, very abundant in northern part of unit, moderately abundant in southern part. Concentration of sphene in rock roughly mimics concentration of biotite. Allanite is very abundant; zircon and apatite occur in trace amounts. All rock is gneissic to some degree and displays incipient to strong ductile grain-size reduction in thin section. Fabric development strongest in northern part of unit, decreasing irregularly southward. Unit appears to be pre-existing pluton caught up within, and stretched out between, various units of Priest River complex. Presence of abundant sphene, and probable secondary muscovite and opaque minerals interleaved with biotite, suggests pre-existing pluton may have been hornblende-biotite body. Zircon uranium-lead age between 90 and 95 Ma (J.L. Wooden, written commun., 1994); Archibald and others (1984) report 94 Ma uranium-lead age on zircon from gneiss of Corn Creek, which is probable extension of unit in Canada

₥pl **Monzonite of Long Canyon (Mesozoic)**—Hornblende-pyroxene monzonite to quartz monzonite (fig. 3). Forms elongate body in northeastern part of Priest River complex. Extremely heterogeneous with respect to composition, color index, grain size, and texture. Average plagioclase composition is calcic oligoclase; nearly all plagioclase is conspicuously unzoned. Potassium feldspar appears to be mostly microcline but some could be orthoclase, especially in southern part of body. Quartz averages about 3 percent but ranges to 10 percent. Pyroxene is ferroaugite; hornblende appears to be ferrohastingsite. Color index ranges from 6 to 20, averaging 8. Unit contains very abundant sphene, allanite, and apatite; locally these minerals are up to 5 mm long. Grain size of other minerals range from fine to coarse; in much of pluton 3- to 8-mm-long, crudely tabular potassium feldspar grains and scattered 3 to 5 mm grains of pyroxene and amphibole are enclosed in matrix of 1 to 3 mm equant grains of all minerals. Unit has subtle lineation or foliation that varies irregularly on outcrop scale. Contains inclusions of schist and gneiss and is cut by numerous dikes that constitute up to 20 percent of unit in places. Body appears to be pre-existing pluton caught up within younger rocks of Priest River complex, but unit is considered part of complex. Mesozoic age based on compositional and textural similarity of pluton to other alkalic bodies of Jurassic or Triassic age and on compositional dissimilarity to Tertiary and most Cretaceous rocks in region

Yppm **Prichard Formation, metamorphosed (Middle Proterozoic)**—Medium- to coarse-grained schist, quartzite, hornfels, and amphibolite variably intruded by pegmatite, alaskite, and two-mica granitic rocks of Priest River complex. Schist locally contains aluminosilicate minerals or garnet; abundance of oversized clots of muscovite are probably altered aluminosilicate minerals indicating most of unit has undergone retrograde metamorphism. Rocks are highly deformed; folded on all scales. Interlayered quartzite, schist, and amphibolite bands pinch and swell or are otherwise discontinuous and appear to be segments of fold limbs offset by faulting along fault hinges. No bedding or sedimentary features are recognized; all layering appears to be secondary. South and east of Continental Mountain, eastern part of rocks mapped as Prichard Formation is highly recrystallized and deformed, indistinguishable from metamorphosed Prichard Formation on west side of Purcell Trench. They are not included in this unit because the gradational zone into Prichard Formation is hundreds of meters wide, and a contact could not be placed objectively or consistently. Locally, within 4 km of Purcell Trench, incipient to moderate mylonitic fabric developed in rocks of this unit

End of granitic and metamorphic rocks of the Priest River complex

Kg **Monzogranite of Granite Pass (Cretaceous)**—Medium- to coarse-grained, leucocratic muscovite monzogranite (fig. 3). Forms single, oval-shaped pluton 3 km west of Upper Priest Lake. Eastern part of pluton lies in Bonners Ferry quadrangle; western part underlies additional 17 km^2 in adjacent quadrangle. Unit averages 6 percent muscovite; contains minor biotite locally around margins. Color index is 0 for most of unit, nowhere greater than 3 around margins. Locally garnet-bearing. Potassium feldspar is microcline; plagioclase is albite (an_3). Nonporphyritic; contains no directional fabric. Relatively uniform lithologically; highly evolved petrogenetically. Muscovite gives potassium-argon age of 98 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977)

Ktmc **Two-mica monzogranite or granodiorite of Twenty Mile Creek (Cretaceous)**—Medium- to coarse-grained, two-mica monzogranite or granodiorite. Forms single, near-circular pluton 1 km east of Naples (fig. 2) surrounded by Cretaceous biotite-hornblende granodiorite of Kelly Pass (Kkp) on all but northwest side. Average plagioclase composition is calcic oligoclase. Potassium feldspar is microcline. Color index averages about 8; biotite is only mafic mineral. Biotite to muscovite ratio averages 3:1. Grain size highly variable. Most of pluton characterized by 5- to 8-mm-wide muscovite grains, distinctly larger than other minerals. Margin is noticeably finer grained than typical interior rocks, but interior contains irregular shaped zones of mixed fine- and coarse-grained rocks. Except for large muscovite grains, texture is even grained to seriate. Age considered Cretaceous on basis of textural and compositional similarity to nearby Cretaceous two-mica rocks

Ktc **Monzogranite of Tango Creek (Cretaceous)**—Very porphyritic, medium- to coarse-grained biotite monzogranite (fig. 3) containing trace, but ubiquitous, muscovite. Forms irregularly shaped pluton centering on north part of Priest Lake; east part of pluton faulted away by Newport Fault. Average plagioclase composition is intermediate oligoclase. Unit is distinguished by pale-pink, sharp-edged orthoclase phenocrysts to 10 cm long containing patches of perthitic microcline. Concentration of phenocrysts varies greatly over short distances. Quartz typically forms large gray crystals and crystal aggregates 1 cm across. Biotite is only mafic mineral; color index about 7. Unit averages 0.7 percent muscovite. Muscovite grains distinctly smaller than biotite grains and may or may not be primary. Rock contains trace amounts of sphene. Unit is nonfoliate and nonlineate, but phenocrysts are aligned locally. Pluton has crude textural zonation; medium- to coarse-grained core is roughly concentric with outer relatively coarser grained margin, but is slightly elongate in east-northeast direction. Fine-grained and coarse-grained parts not internally uniform. Biotite gives potassium-argon age of 90 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977); this is considered a minimum age

Kh **Monzogranite of Hungry Mountain (Cretaceous)**—Medium- to coarse-grained, porphyritic muscovite-biotite monzogranite, locally ranging to granodiorite (fig. 3). Forms a pluton that underlies small area in southwestern part of quadrangle and about 90 km^2 in quadrangle to west. Characterized by abundant, irregularly distributed 3- to 7-cm-long white microcline phenocrysts; in some areas rock is over 50 percent phenocrysts, in other areas, contains almost none. Plagioclase highly zoned; average composition an_{20}. Biotite is only mafic mineral; color index averages 7. Muscovite forms smaller crystals than other minerals in rock and does not exceed 1 percent. Rock has no penetrative fabric, but phenocrysts are locally aligned, commonly forming arcuate rather than liner pattern. Monzogranite of Hungry Mountain grades inward to monzogranite of Gleason Mountain (Kgm) through decrease in grain size and concentration of phenocrysts. Muscovite and biotite give potassium-argon ages of 97 Ma and 93 Ma, respectively (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977)

Kgm **Monzogranite of Gleason Mountain (Cretaceous)**—Leucocratic, muscovite-biotite monzogranite locally ranging to granodiorite (fig. 3). Modally, chemically, and mineralogically, monzogranite of Gleason Mountain is same as monzogranite of Hungry Mountain but is slightly less mafic. Color index averages 7. Pluton characterized by extreme variations in grain size, even in small exposures. Typical rock is medium grained, but centimeter-size pods to areas several hundred square meters range from fine to coarse grained. Irregular-shaped pods of pegmatite and alaskite having diffuse, gradational borders are found throughout pluton. Contains sparse, poorly formed, irregularly distributed phenocrysts up to 4 cm long. Grades outward through increasing grain-size, biotite, and phenocrysts into monzogranite of Hungry Mountain. Considered Cretaceous on basis of physical and petrogenetic relationship with monzogranite of Hungry Mountain

Kcu **Granitic rocks, undivided (Cretaceous)**—Medium- to coarse-grained hornblende-biotite and biotite granodiorite and monzogranite. Forms several, small, noncontiguous plutons in Cabinet Mountains (fig. 2) and are probably not genetically related to one another. Color index ranges from about 5 to 20 but is relatively uniform within a given body; all rocks contain biotite. Most plutons of this unit lie south of Bonners Ferry quadrangle. Body near Middle Mountain at south edge of quadrangle is coarse grained, leucocratic monzogranite. Bennett and others (1975) describe another body located 10 km farther south that closely fits description of granodiorite of Kelly Pass (Kkp). Plutons included in this unit are considered Cretaceous on basis of similarity to nearby granitic rocks of that age

Mzw **Monzonite of Wall Mountain (Mesozoic)**—Pyroxene-hornblende quartz monzonite. Forms single, small pluton 12 km east of Copeland (fig. 2). Average plagioclase composition is intermediate to calcic oligoclase. Potassium feldspar is orthoclase containing sparse microperthitic intergrowths; most orthoclase is prominently zoned and displays carlsbad twins. Color index averages 18. Pyroxene is augite and hornblende appears to be ferrohastingsite. Unit contains abundant sphene, epidote, and opaque minerals throughout. Grain size and texture extremely variable over short distances. Grain size ranges from fine to coarse; texture ranges from equigranular to porphyritic. Aligned tabular orthoclase phenocrysts up to 2 cm long impart primary planar fabric which is parallel with outer margins of pluton. Hornblende gives potassium-argon age of 131 Ma (R. Fleck, U.S. Geological Survey, written comm., 1988). Age is considered to be cooling age, because pluton is located in area where some potassium-argon ages of mineral pairs from other plutons are discordant. Emplacement age is inferred to be Mesozoic, probably Jurassic or Triassic, on basis of compositional and textural similarities to other alkalic rocks of that age range, but could be Cretaceous

Kbf **Granodiorite of Bonners Ferry (Cretaceous)**—Medium- to coarse-grained muscovite-biotite granodiorite. Average plagioclase composition is calcic oligoclase. Potassium feldspar is microcline. Biotite is only mafic mineral; color index averages 16, much higher than most two-mica granitic rocks in region. Characterized by very abundant epidote, much having allanite cores. Allanite primary; epidote possibly primary. Unit has subtle foliation in places and thin, distributed, brittlely deformed zones, some heavily chloritized, in westernmost exposures. Sparse, small, but wide-spread exposures suggest pluton underlies entire valley south of Bonners Ferry, nearly to Moravia. Because less than one percent of pluton is exposed, average composition and texture may differ from described rock. Biotite gives potassium-argon age of 89 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977), which is considered cooling age, not emplacement age

Granodiorite of Hall Mountain (Cretaceous)—Forms six noncontiguous plutons. Except for eastern part of pluton located 6 km southwest of Upper Priest Lake (fig. 2), all are west and southwest of Bonners Ferry quadrangle. Within quadrangle, unit consists only of Boulder Mountain Pluton

Khbm **Boulder Mountain pluton**—Medium- to fine-grained biotite granodiorite (fig. 3) containing only trace muscovite. A single pluton 6 km southwest of Upper Priest Lake underlies about 5 km^2 west of quadrangle. Plagioclase averages about an_{30}; potassium feldspar is microcline. Mafic content locally variable; average color index is 13 but ranges up to 17. Biotite shows wide range in grain size. Accessory minerals include abundant epidote and allanite and moderately abundant apatite and zircon; there is conspicuous dearth of opaque minerals. Texture generally seriate; grain-size variable, noticeably finer grained and slightly foliate near margins. Castor and others (1981) report core of fine-grained to microcrystalline porphyry and extensive alteration near center of pluton. Numerous large veins and pods of quartz, some containing molybdenite, are present in southern part of pluton. Probably petrogenetically related to granodiorite of Reeder Creek. Biotite and muscovite from noncontiguous granodiorite of Hall Mountain Pluton west of quadrangle give potassium-argon ages of 99 Ma and 96 Ma, respectively (Miller and Frisken, 1984)

Krc **Granodiorite of Reeder Creek (Cretaceous)**—Medium- and coarse-grained, muscovite-bearing, biotite granodiorite (fig. 3). Large irregularly shaped pluton centering on south half of Priest Lake; eastern part faulted away by Newport Fault. Characterized by 2-cm-wide, irregularly shaped, poikilitic microcline grains which contain scattered, randomly oriented, euhedral plagioclase grains; imparts spongy appearance to slabbed rocks stained for feldspars. Average plagioclase about an_{30}. Biotite is only mafic mineral; forms ragged-edge crystals that vary more in size than other minerals in rock. Average color index is 11. Contains ubiquitous, fairly abundant epidote and allanite. Zircon, apatite, and opaque minerals are accessories. Texture is hypidiomorphic-granular to seriate. Composition and texture relatively uniform through most of pluton, except for separately mapped porphyritic phase (Krcp) on east side of Priest Lake and along northwestern and southwestern borders of pluton, where rocks are much more mafic and noticeably lineate. Biotite gives potassium-argon age of 94 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977); this is considered a minimum age. Unit includes porphyritic granodiorite, mapped separately

Krcp **Porphyritic, muscovite-bearing, biotite granodiorite**—Found only in limited area on east side of Priest Lake in northern part of Reeder Creek Pluton. Appearance and composition similar to granodiorite of Reeder Creek at other places, except for moderately abundant, well-formed, 2.5- to 4-cm-long microcline phenocrysts

Kgp **Galena Point Granodiorite (Cretaceous)**—Porphyritic, medium- to coarse-grained biotite granodiorite and monzogranite; average composition is granodiorite (fig. 3). Found only in southwesternmost part of quadrangle in hanging wall of Newport Fault; underlies about 170 km^2 in Chewelah and Colville 30' x 60' quadrangles to southwest and west, respectively. Phenocrysts are microperthitic orthoclase but in parts of pluton are microcline; phenocrysts range in size from 2 to 8 cm and average 4 cm. Groundmass potassium feldspar shows no microcline twinning. Plagioclase composition averages an_{25}. Biotite is only mafic mineral except for traces of hornblende locally west of quadrangle where pluton is in contact with granodiorite of Yocum Lake. Average color index is 12. Accessory minerals include apatite, zircon, opaque minerals, and minor allanite. Groundmass texture hypidiomorphic-granular to seriate. Except for phenocryst size, texture and composition are very uniform throughout most of pluton. Outer part of pluton and nearby country rocks contain numerous leucocratic dikes. May grade over narrow interval into granodiorite of Yocum Lake, but contact relations are ambiguous. Biotite gives potassium-argon age of 101 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977)

Kru **Granodiorite of Ruby Creek (Cretaceous)**—Coarse-grained, porphyritic biotite granodiorite (fig. 3). Forms single pluton 5 km north of Upper Priest Lake; west part faulted away by Newport Fault. Nearly all potassium feldspar forms 3- to 5-cm-long phenocrysts, almost none in groundmass. Plagioclase composition ranges from an_{30} to an_{45}, averages about an_{35}. Biotite is only mafic mineral despite high color index averaging 20. Contains abundant, unusually large sphene. Epidote common as overgrowths on allanite and as anhedral crystals. Besides sphene and epidote-group minerals, accessory minerals include apatite, zircon, ilmenite, and possibly magnetite. Texture is porphyritic with hypidiomorphic-granular groundmass. Biotite gives potassium-argon age of 68 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977), which is considered to be cooling age. Rock is texturally and compositionally similar to nearby 100 Ma-old plutons

Kco **Granodiorite of Copeland (Cretaceous)**—Porphyritic, medium- to coarse-grained hornblende-biotite and biotite granodiorite. Forms single large pluton, most of which lies southeast of Copeland (fig. 2). Plagioclase composition averages an_{28}. Most potassium feldspar is microcline, but some in groundmass may be perthitic orthoclase. Microcline phenocrysts are as much as 4 cm long. Color index ranges from 13 to 17; biotite is more than twice as abundant as hornblende in most of pluton. Accessories include zircon, apatite, opaque minerals, allanite, epidote, and very abundant sphene. Eastern part of pluton is fairly uniform with respect to texture and composition and is highly porphyritic. Rocks forming sparse, noncontiguous outcrops in western part are irregularly porphyritic, do not contain hornblende, have variable, but noticeably lower, color index, and may represent separate pluton. Rocks in westernmost exposures near Kootenay River are highly brecciated locally. Hornblende and biotite give potassium-argon ages of 95 Ma and 90 Ma, respectively (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977); emplacement age inferred to be about 100 Ma

Kgpl **Granodiorite of Priest Lake (Cretaceous)**—Medium- to coarse-grained hornblende-biotite granodiorite (fig. 3). Forms highly irregular body in and west of Priest Lake and in hanging wall of Newport Fault. Average plagioclase composition an_{30}. Potassium feldspar is microperthitic and nonperthitic orthoclase. Some orthoclase forms poikilitic grains having spongy texture similar to that in granodiorite of Reeder Creek (Krc). Hornblende forms stubby 1-cm-long crystals and smaller grains; hornblende is almost as abundant as biotite in some rocks but hornblende to biotite ratio varies widely. Average color index is 17. Very abundant sphene is conspicuous in all outcrops. Other accessory minerals include zircon, apatite, opaque minerals, and abundant epidote and allanite. Texture is hypidiomorphic-granular, nonporphyritic, nonfoliate. Unit is very uniform with respect to texture and composition. Sphene gives uranium-lead age of 101 Ma; zircon gives uranium-lead age of 93 to 103 Ma (J.L. Wooden, written commun., 1994)

Kkp **Granodiorite of Kelly Pass (Cretaceous)**—Highly porphyritic, very coarse grained biotite-hornblende and hornblende granodiorite and monzogranite. Forms nearly circular pluton surrounding monzogranite of Twentymile Creek and is partly surrounded by discontinuous bodies of rock considered to be Cretaceous granodiorite of Road V-78 (Kv). Conspicuously blocky microcline phenocrysts from 3 to 10 cm long make up 25 percent of rock. Average plagioclase composition is sodic andesine. Color index about 16. Hornblende to biotite ratio varies from 1:1 to rocks containing hornblende as only mafic mineral; average rock has less than 2 percent biotite. Very abundant sphene, much of which is coarse grained. Most rocks contain 0.5 to 1 percent epidote, probably secondary. Zircon, apatite, opaque minerals, and allanite are accessory minerals. Unit may be related to granodiorite of Road V-78. Appears to grade into that rock through decreasing hornblende and phenocrysts and increasing biotite and fabric development. Bulk chemistry of two units is nearly identical. Hornblende from northeastern part of pluton yields potassium-argon age of 99 Ma (J. Nakata, written commun., 1993)

Kv **Granodiorite of Road V-78 (Cretaceous)**—Medium- to coarse-grained biotite granodiorite. Found only as isolated exposures in and south of Bonners Ferry; unit probably underlies large area covered by Quaternary deposits south of Bonners Ferry. In Bonners Ferry area, contains abundant 2- to 3-cm-long microcline megacrysts, almost all of which are rounded and poorly formed. On west and southeast sides of granodiorite of Kelly Pass (Kkp), megacrysts are sparse. Average plagioclase composition is sodic andesine. Biotite is dominant mafic mineral; average color index about 15. Most rocks contain hornblende ranging from trace amounts up to 2 percent. Epidote is very abundant and obvious to unaided eye in all rocks. Sphene is very abundant. Rock is lineate and moderately foliate; rounded megacrysts lie in plane of foliation and are elongate parallel to trains of biotite to define lineation. Many sphene crystals are deformed. Grain size of some felsic minerals and biotite is tectonically reduced, but grains were subsequently recrystallized. Unit may be related to granodiorite of Kelly Pass. Appears to grade into that rock through increasing hornblende and phenocrysts and decreasing biotite and fabric development. Bulk chemistry of two units is nearly identical. Biotite gives potassium-argon age of 89 Ma (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977), considered to reflect cooling history but probably not emplacement age

Jcm **Tonalite of Continental Mountain (Jurassic)**—Medium- to coarse-grained biotite tonalite ranging to granodiorite (fig. 3). Forms single large pluton and several small, aligned, noncontiguous bodies in northwestern part of quadrangle. Average plagioclase composition is calcic oligoclase. In thin section, plagioclase is water clear and almost totally free of sericitic alteration found in most plutonic feldspar. Euhedral clinozoisite and muscovite are included in plagioclase and are oriented along two and three planes that are not concentric with outer crystal forms of plagioclase. Potassium feldspar is microcline, very sparse, occupies interstices between other minerals, and is also water clear. Average color index is 17. Biotite is essentially sole mafic mineral, but some rocks contain very rare, sub-millimeter, anhedral grains of hornblende. Biotite forms mineral trains interstitial to, and wrapped around, felsic minerals. Rock is characterized by very abundant pale-green epidote and clinozoisite, some having allanite cores. Unit also contains abundant sphene and trace amounts of garnet, zircon, apatite, and opaque minerals. Texture is dominated by interstitial biotite wrapped around felsic minerals; rocks have subtle foliation in parts of pluton. Mineralogy and texture suggest pluton has been metamorphosed and may have originally been hornblende-biotite body. Biotite from tonalite gives potassium-argon age of 107 Ma; (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977). Zircon gives uranium-lead age of 120 Ma; sphene gives uranium-lead age of 168 Ma (J.L. Wooden, written commun., 1994), which is considered to be emplacement age

Jcmt **Trondhjemite of Continental Mountain (Jurassic)**—Coarse-grained muscovite-biotite trondhjemite (fig. 3). Forms small body on east side of tonalite of Continental Mountain (Jcm). Plagioclase composition, absence of alteration, and inclusion of euhedral muscovite and clinozoisite in feldspar is same as in tonalite of Continental Mountain. Texture and interrelation of mica and felsic minerals also similar to those in tonalite of Continental Mountain. Chief difference in trondhjemite unit compared to tonalite unit is lower color index and presence of muscovite that may be primary. Color index of trondhjemite averages about 9; biotite to muscovite ratio ranges from 10:1 to 3:1. Hornblende and sphene are found near contact with tonalite but are extremely rare. Unit appears to have undergone same metamorphism as tonalite of Continental Mountain, but the unit may not have originally been hornblende-biotite body. Biotite and muscovite from trondhjemite give ages of 101 Ma and 96 Ma, respectively (Miller and Engels, 1975, recalculated using current IUGS constants of Steiger and Jaeger, 1977); ages are probably reset. Considered to be same age as tonalite of Continental Mountain on basis of association and similar metamorphic history

€l **Dolomite (Cambrian)**—Interbedded dark- and light-gray dolomite. Restricted to single fault-bounded sliver on east side of Moyie Fault 8 km north-northeast of Moyie Springs (fig. 2). Dark-gray dolomite is thin bedded and contains irregularly distributed patches of white dolomite. Light-gray beds are even-parallel laminated but in most exposures are highly deformed. All rocks are extremely fetid when broken. Internal stratigraphy, direction of stratigraphic top, age, and thickness cannot be determined from available exposures (Burmester, 1986). Probably correlative with Middle Cambrian Lakeview Limestone found 83 km to south (Harrison and Jobin, 1965), which is sole Paleozoic carbonate rock in region east of Purcell Trench, and is predominantly dolomite in upper part

Windermere Group (Late Proterozoic)—Found only in northwesternmost part of quadrangle and represented only by Shedroof Conglomerate. A few kilometers west of Bonners Ferry quadrangle, Shedroof Conglomerate is overlain by rest of Windermere Group: from oldest to youngest, Leola Volcanics, Monk Formation, and Three Sisters Formation (Miller, 1994). There, aggregate thickness of Windermere Group is about 8,000 m. No Windermere Group rocks are found east of Jumpoff Joe Fault

Zsc **Shedroof Conglomerate**—Conglomerate; diamictite; sandy siltite and argillite; lithic, feldspathic quartzite; and minor sandy limestone. Lower third to half of formation is matrix-supported conglomerate and diamictite containing sparse interbeds of lithic, feldspathic quartzite; this part of formation is predominantly tan and has abundant carbonate minerals in groundmass. Clast size ranges from less than 1 cm to more than 1 m. Dolomite and argillite derived from Deer Trail Group are most common clast types, but granitic clasts of unknown provenance are abundant in some horizons. Sorting is poor; degree of roundness poor to good. Most clasts are flattened, elongated, and oriented parallel to pervasive cleavage found throughout formation. Upper part of formation is similar to lower part but color is pale to medium green and reflects increased chlorite content of matrix. Formation contains numerous greenstone layers that are probably extrusive volcanic rocks. A few kilometers west of quadrangle, middle part of Shedroof Conglomerate contains southwestward-thickening wedge of green and gray phyllite and sandy phyllite that reaches maximum thickness of 2,000 m 16 km west of quadrangle. Phyllite wedge contains two 100- to 150-m-thick zones of gray, sandy limestone. Shedroof Conglomerate is correlative with Toby Conglomerate in southern British Columbia (Reesor, 1957). From section within and west of Bonners Ferry quadrangle, thickness of Shedroof Conglomerate as calculated from outcrop width is 3,200 m; however, Shedroof Conglomerate exhibits order-of-magnitude thickness differences across syndepositional faults (Miller, 1994)

ZYmi **Mafic intrusive rocks (Late or Middle Proterozoic)**—Medium- to fine-grained sills of diabase composition intruding Wallace Formation. Lithologically, essentially indistinguishable from sills (Ymi) intruding Prichard Formation (Yp). However, sills in Prichard Formation are considered older than Wallace Formation (Cressman, 1989). Sills in Wallace Formation may be related to Middle Proterozoic Purcell Lavas found 25 km east of Bonners Ferry quadrangle or, less likely, to volcanic rocks of Late Proterozoic Windermere Group; the latter are not known to exist east of Jumpoff Joe Fault

Deer Trail Group (Middle Proterozoic)—Deer Trail Group crops out exclusively in a north-northeast-striking belt in northwestern part of quadrangle and is restricted solely to west side of Jumpoff Joe Fault. From youngest to oldest, Deer Trail Group consists of Buffalo Hump Formation, Stensgar Dolomite, McHale Slate, Wabash Detroit Formation, Chamokane Creek Formation, and Togo Formation (Miller, 1996a). All units of Deer Trail Group are highly faulted and internally deformed in Bonners Ferry quadrangle, especially argillite units or units containing appreciable amounts of argillite. Deer Trail Group is lithostratigraphic equivalent of part of upper part of Belt Supergroup (Miller and Whipple, 1989)

Ybq **Buffalo Hump Formation**—Vitreous quartzite, subordinate phyllite, and minor phyllitic siltite and lithic conglomerate. Quartzite and argillite show considerable range in appearance and possibly vary in relative abundance from place to place. Quartzite is white to medium gray. In quadrangle, contains very little feldspar, but in Chewelah quadrangle, parts of unit are highly feldspathic. Most is medium grained, but some ranges to very coarse grained. Nearly all quartzite is so highly recrystallized that primary grain shapes are unrecognizable. Pebbles of quartzite and argillite 0.5 to 1 cm across are sparsely scattered in some layers; local concentrations of pebbles define bedding. Quartzite appears to be medium to thick bedded, but internal deformation, recrystallization, and possible transposition leave interpretation of bed-like features open to question. Quartzite layers separated by featureless gray and greenish-gray phyllite layers 1 cm to several meters thick. Quartzite and phyllite layers alternate in no identifiable order. All phyllite is highly deformed and cleaved. Quartzite appears to make up most of formation in Bonners Ferry quadrangle; in type section, 100 km to southwest in Chewelah quadrangle, formation contains much higher proportion of argillite. Upper contact everywhere faulted in Bonners Ferry quadrangle, so dearth of argillite here could be due to either faulting or change in lithofacies. Variability in relative amounts of each lithology may be more apparent than real, resulting more from poor exposure than from faulting or changes in lithofacies. In Chewelah area to southwest, upper part of Buffalo Hump Formation is largely argillite (Miller, 2001); upper part of formation is not exposed in Bonners Ferry quadrangle. Maximum thickness of Buffalo Hump Formation is about 430 m as calculated from outcrop width, but figure is only an approximation due to internal deformation

Ys **Stensgar Dolomite**—Dolomite with minor interbedded argillite. Most of formation is white, tan, or gray dolomite. Faulting, folding, and incomplete exposure preclude systematic delineation of internal stratigraphy, except in general terms, but some of following relations appear to be consistent in more than one fault-bounded section. Gray, lavender-gray, and maroon phyllitic argillite beds in sequences up to 3 m thick are restricted chiefly to sharply defined intervals in upper and middle parts of formation. Lower part of formation contains distinctive gray-weathering, medium- to thin-bedded dolomite; no other carbonate rocks of Deer Trail Group are known to weather gray. Upper half of formation is thicker bedded, tan, gray or white, tan weathering, and contains abundant nodular chert. At least one argillite zone in upper half of formation contains octahedral casts of what may have been evaporite minerals. Crystal form and mud-matrix-supported occurrence suggest mineral may have been northupite ($MgCO_3 \bullet Na_2CO_3 \bullet NaCl$) (Wasson and others, 1984). May indicate primary origin for large magnesite deposits southwest of Bonners Ferry quadrangle near Chewelah (fig. 1) that are confined to Stensgar Dolomite. Stensgar appears to grade into underlying McHale Slate over about 20 m, but contact zone where not faulted is poorly exposed. Thickness calculated from outcrop width 1 km west of quadrangle is 300 m

Ym **McHale Slate**—Formation is almost entirely argillite. In Bonners Ferry quadrangle, dominant lithology is highly phyllitic, medium- to dark-gray argillite with tan, pale-gray, and white laminae. Where bedding is preserved, thickness ranges from laminations on sub-millimeter scale to fining-upward couplets as much as 3 cm thick. Parallel-planar lamination common although extensively disrupted by soft-sediment deformation. Wavy-parallel and wavy-nonparallel beds are also abundant; some have prominent erosional bases. Most McHale Slate in quadrangle is folded, highly cleaved, and bedding may be transposed. Because of deformation, unit is very difficult to distinguish from Togo Formation; distinguished chiefly by association with bounding units. Southwest of Chewelah (fig. 1), upper two-thirds of formation is pale greenish gray or lavender gray (Miller, 1996a, 1996b); this pigmentation is not found in Bonners Ferry quadrangle. Thickness calculated from outcrop width is about 300 m, but due to internal deformation probably bears little relation to stratigraphic thickness

Ywcu **Wabash Detroit Formation and Chamokane Creek Formation, undivided**—Highly sheared, faulted, and internally deformed carbonate-bearing quartzite and siltite, dolomite, carbonate-free quartzite and siltite, and subordinate argillite. Formations are mapped undivided because everywhere in Bonners Ferry quadrangle faulting, shearing, tight folding, and transposition of bedding has deformed both formations to a degree that they cannot be distinguished from one another. All or most layering in unit is probably not primary bedding, but transposed bedding. Southwest of Chewelah (fig. 1), both formations are less deformed (Miller, 1996a, 1996b). There, Wabash Detroit Formation consists of dolomite interbedded with subordinate argillite, quartzite, and carbonate-bearing quartzite and siltite; Chamokane Creek Formation consists of carbonate-bearing and carbonate-free quartzite and siltite interbedded with subordinate dolomite and argillite and contains a distinctive vitreous quartzite zone in upper half. Although Wabash Detroit and Chamokane Creek Formations are mapped undivided in Bonners Ferry quadrangle, proportions of various lithologies that make up combined formations differ markedly from lithologic proportions of combined formations southwest of Chewelah; these differences suggest substantial changes in lithofacies between the two sections. In section southwest of Chewelah, distinctive vitreous quartzite zone in upper half of Chamokane Creek Formation is 150 m thick. In Bonners Ferry quadrangle, same quartzite zone appears to be much thicker and not all of it is vitreous quartzite. Thickness of undivided formations is indeterminate due to internal deformation. Predominantly quartzitic part of unit is mapped separately

Ycq **Quartzite unit**—Fine to very fine grained vitreous and nonvitreous quartzite, siltite, and lesser interbedded argillite. Most quartzite and siltite is white, but some in upper part, which may be feldspathic and contain small amounts of carbonate cement, is pale tan. All quartzite and siltite contains secondary mica or pale-green chlorite in well-formed crystals along bedding or foliation planes. Most quartz grains are angular and probably do not represent sedimentary grain shapes; none exhibit overgrowths or have rounded cores. Where preserved, bedding and lamination range from even parallel to wavy nonparallel. Sedimentary features that are locally preserved well enough to reliably interpret include crossbedding, soft-sediment deformation, compaction features, syneresis cracks, and fluid-escape structures

Yt **Togo Formation**—Medium- and dark-gray argillite with subordinate beds and intervals of green argillite and green and gray siltite. In quadrangle, almost all argillite in Togo Formation is highly deformed and highly phyllitic; bedding or other sedimentary features are preserved only locally. Much layering in unit is transposed bedding. Contains rare, thin, sharply defined beds or layers of quartzite and dolomite locally. Where preserved, bedding in dark-gray argillite ranges from wavy nonparallel to even parallel. Bedding thickness ranges from submillimeter laminae to about 10 cm; beds thicker than about 2 cm generally show even-parallel bedding. Laminations defined by white or light-gray siltite that weathers orange, possibly reflecting minor carbonate content. Most nonparallel beds have low to moderate angle of convergence between top and bottom; where angle is high, it is caused by soft-sediment deformation, which is common throughout unit. Because most bedding in Togo Formation is probably transposed, it is not certain if preserved bedding features are representative of overall formation. All Togo sections in quadrangle are fault bounded and thickness is unknown. Southwest of Chewelah, Washington, unit is probably between 800 m and 2,000 m thick (Miller, 2001)

Belt Supergroup (Middle Proterozoic)—Forms thick sequence of intermixed quartzite, siltite, argillite, dolomite, and minor limestone. Nearly all rocks described as dolomite and limestone contain clastic material, typically silt-size quartz and feldspar. Most of Belt Supergroup in quadrangle is east of Purcell Trench (fig. 2); a small part of Newport sequence of Belt Supergroup (fig. 1) occurs in western part of quadrangle. Formations of Belt Supergroup east of Purcell Trench are same as those in Newport and Chewelah Belt sequences (fig. 1), but many units differ in thickness and lithofacies. Upper contact of Belt Supergroup is faulted everywhere in quadrangle; 22 km southwest of quadrangle, Belt Supergroup is unconformably overlain by Late Proterozoic and Cambrian quartzite. Lower contact of Belt Supergroup nowhere exposed in quadrangle.

Mount Shields Formation—Quartzite, siltite, argillite, and dolomite; highly varied lithologically. Characterized by Maroon and green color, domal stromatolites, and abundant and varied sedimentary structures

Ymsu **Upper part**—Siltite, argillite, and dolomite. As mapped here, upper part of Mount Shields Formation corresponds closely to member 3 of Harrison and others (1992). Unit is dominated by green siltite that contains partings of green and maroon argillite. It forms a generally upward thickening sequence, but thin, light- to dark-green siltite-argillite couplets are scattered throughout unit. Carbonate rocks and carbonate-bearing rocks are also found throughout and are interspersed with carbonate-free siltite and argillite. Orange-brown-weathering, blue-gray dolomite occurs in upper part of unit; some is oolitic. Sharp-crested stromatolites are abundant in upper part; carbonate-bearing siltite is abundant in lower part. Thinner beds are typically uneven, nonparallel graded couplets ranging in thickness from several millimeters to several centimeters. Polygonal mud cracks, mudchip breccia, oscillation ripple marks, and salt casts are common, especially in maroon argillite. Thickness calculated from outcrop width in southern part of quadrangle is 420 m; upper contact is faulted

Ymsl **Lower part**—Interbedded quartzite, siltite, argillite, and dolomite. As mapped here, lower part of Mount Shields Formation corresponds closely to members 1 and 2 of Harrison and others (1992). Upper part of lower unit is characterized by layers of broadly domal stromatolites enclosed in maroon argillite, containing interbeds of rounded quartz grains and oolites. At localities outside Bonners Ferry quadrangle, boundary between members 2 and 3 of Harrison and others (1992) may be placed below this stromatolite horizon (Winston and Woods, 1986). Lower part of formation also includes green, pink, and white micaceous quartzite; green, carbonate-bearing quartzite, some oolitic; and green siltite. In general, carbonate content, grain size, and bed thickness increase upward in unit, but within individual 30- to 60-cm-thick layers, grain size fines upward. Parting is prominent and grades progressively upward in unit from platy through slabby to blocky. Mica in quartzite is detrital. Polygonal mud cracks, mudchip breccias, and oscillation ripple marks are common. Some quartzite is cross laminated. Thickness calculated from outcrop width ranges from 150 m just east of quadrangle to 290 m five kilometers northeast of Moyie Springs (fig. 2)

Yhm **Argillite of Half Moon Lake**—Argillite, siltite, and lesser quartzite. Compared to bounding formations, unit contains relatively few carbonate-bearing rocks. Unit is characterized by carbonate-free, dark-gray and green argillite, green siltite, and lesser green micaceous quartzite. Argillite and siltite form fining-upward, uneven, nonparallel and parallel-planar laminated couplets 1 to 5 mm thick. Quartzite commonly in lensoidal beds less than 40 cm thick that have channeled bases; some channels have vitreous quartzite at base composed of well-rounded, medium-size quartz grains. Middle part of unit is chiefly dark gray, parallel-planar laminated argillite. Thin beds and pods of stromatolites found throughout unit but concentrated in middle part. Green, carbonate-bearing siltite-argillite couplets and green carbonate-bearing siltite beds similar to those in Shepard Formation are sparsely scattered through unit. Southwest of Bonners Ferry quadrangle in Newport and Chewelah sequences of Belt Supergroup (fig. 1), proportion of dark-gray parallel-planar laminated beds increases at expense of green beds. Measured thickness of unit is 155 m in southern part of quadrangle. Unit corresponds to (1) uppermost 195-m-thick argillite, siltite, and quartzite member of Wallace Formation in Clark Fork area to south (Harrison and Jobin, 1963), (2) upper Shepard Formation (Ysh) farther southeast (Lemoine and Winston, 1986), and (3) 350-m-thick argillite of Half Moon Lake in Newport area to southwest (Miller, 2001)

Ysh **Shepard Formation**—Carbonate-bearing siltite and argillite are dominant lithologies, but lesser amounts of interbedded quartzite, silty dolomite, and carbonate-free argillite are found throughout formation. Bedding in formation is generally lenticular to uneven and wavy, caused at least in part by loading and ripples. Bed thickness ranges from laminations to about 40 cm. Quartzite is commonly pyrite and carbonate bearing. Carbonate-bearing siltite-argillite forms couplets; quartzite occurs as cross-laminated lenses and starved ripples and as even parallel-laminated beds to 40 cm thick; silty dolomite is parallel-planar laminated and contains vertical calcite ribbons. Siltitic rocks are characteristically medium green; argillitic rocks are pale green, weathering yellow brown; quartzite is white; and dolomite is blue-gray. Internal stratigraphy is poorly understood due to incomplete exposure, but generally, dolomite and stromatolites appear to be concentrated in the upper and middle part of unit. Thickness calculated from outcrop width is about 380 m

Yss **Snowslip Formation**—Graded siltite-argillite couplets and lesser interlayered laminated and thin-bedded siltite. Contains minor amount of carbonate minerals, especially compared to carbonate content of bounding formations. Limited microbreccia and small stromatolites in lower part. Pyrite disseminated through most of formation produces orange weathering rind. Siltite and argillite are generally medium green, but also pale to dark green, gray, and purple. Thicker dark siltite beds capped by dark-gray argillite form 200-m-thick zone near middle of formation. Below dark-gray zone is zone in which couplets topped by purple argillite are interbedded with more common green couplets. Most of formation is thinly laminated to thin bedded, but bedding appears to thicken slightly in middle part. Bedding is generally wavy due to abundant ripples and loading; bedding is planar in some parts of lower part of formation and especially in zone of dark-gray couplets near middle of lower part. Wavy-bedded siltite is commonly crosslaminated. Syneresis and large dewatering cracks found through most of unit; mudchip breccia is found locally. Thickness uncertain due to structure and incomplete exposure, but best estimate calculated from outcrop width is about 880 m

Yw **Wallace Formation**—Carbonate-bearing quartzite and siltite, interbedded with dolomite, limestone, and argillite. Various lithologies are highly intermixed. Highest concentration of carbonate-bearing quartzite-siltite beds appears to be in middle part of formation; uppermost part characterized by interbedded limestone and siltite-argillite couplets. Carbonate-bearing quartzite and siltite is white to tan; dolomite and limestone ranges from tan to light and dark gray, weathering tan to reddish tan; most argillite is dark gray to almost black, but some ranges to green hues. Overall coloration of formation is dominated by alternating light-colored quartzite-siltite beds and thinner, very dark colored argillite beds. Entire unit is characterized by uneven bedding that pinches and swells from less than one centimeter to over one meter, commonly in a distance of just a few meters. Small-scale crossbedding, cross-lamination, dewatering features, and shrinkage cracks are common sedimentary structures. Graded couplets are found in finer grained beds. Thickness as calculated from outcrop width ranges from 490 m in east-central part of quadrangle to 1,400 m in southeastern part; higher figure is considered more accurate because of possible faulting in east-central part of quadrangle

Ye **Empire Formation**—Carbonate-bearing siltite and argillite interlayered with carbonate-free zones of finely laminated to thinly bedded siltite and argillite. Most carbonate minerals are concentrated in siltite. Lower part of unit contains thin, discontinuous channels and beds of well-sorted quartzite; upper part contains 2- to 5-cm-long pods of dolomite. Siltite and argillite that make up most of formation are various hues of pale green, except for some interlayered purple beds in lower part. Quartzite layers are white and carbonate pods are tan. Bedding is wavy and nonparallel. Ripples, starved ripples, cross-lamination, and channeling are common. Rare graded couplets are found in some carbonate-free beds. Thickness calculated from outcrop width ranges from 200 m to 580 m; wide variation partly due to probable inconsistent placement of transitional upper and lower contacts caused by incomplete exposure

Ysr **St. Regis Formation**—Argillite and fine-grained siltite in graded couplets; some quartzite in lower part of unit and carbonate-bearing siltite in upper part. Unit generally is fining- and thinning-upward sequence. Argillite is pale purple or maroon; most siltite and quartzite is white, but ranges to very pale purple with purple banding. Latter coloration restricted chiefly to lower part of unit. Most carbonate-bearing beds and some carbonate-free argillite and siltite in upper part are pale green. Abundance of pale-green argillite-siltite couplets progressively increases upsection. Bedding is uneven and lensoidal. Unit is characterized by abundant mud cracks, mud-chip breccia, cross-lamination, ripple marks, and fluid-escape structures. Thickness calculated from outcrop width of most completely exposed sections ranges from 250 to 470 m. Inconsistent placement of lower contact at top of highest, thick, white quartzite bed of Revett Formation may account for wide range in thickness, or unrecognized faults may account for apparent northward thinning

Yr **Revett Formation**—Quartzite and lesser siltite and argillite. Forms discontinuous band east of Moyie Fault. Unit appears to consist of 8 to 10 intervals of quartzite separated by thinner intervals of interbedded argillite, siltite and quartzite. Most quartzite is white, but some is purple and pale purple; siltite is pale green; and argillite is purple. Quartzite is medium to thick bedded; siltite and argillite is medium to thin bedded. Cross-lamination, ripple marks, and load features found locally. Abundant large-scale crossbedding, which is common in Revett sections to south, is rare. Also, clear lithologic distinction between Burke Formation and Revett Formation found in sequences to south is less apparent in Bonners Ferry quadrangle, probably reflecting greater distance from source of Revett Formation sediment. Calculated thickness of composite section based on outcrop widths of most completely exposed partial sections ranges from minimum of 570 m to maximum of 750 m. Greater thickness within and west of quadrangle, compared to reported thicknesses (Harrison and others, 1992) to east, is due to differing criteria used to place contact with underlying Burke Formation

Ybk **Burke Formation**—Siltite with minor amounts of argillite and quartzite. Best and most complete sections are found east of Moyie Fault. Lower part of formation is medium- to thin-bedded, green and gray siltite that is characterized by slabby to platy parting. Weathered surfaces are characteristically much lighter than fresh rock. Carbonate minerals are found in rare thin beds and nodules near base of formation. Upper part of formation is mostly gray and green siltite similar to that in lower part but contains numerous interbeds of purple argillite, purple laminated siltite, and fine-grained quartzite. Magnetite octahedra up to 1 mm across are sparse to abundant throughout formation. Limited exposures of Burke Formation west of Upper Priest Lake are medium- to pale-gray siltite. Thickness of best exposed section east of Moyie Springs is about 1,360 m

Ymi **Mafic sills**—Medium- to fine-grained sills of tholeiitic composition intruding Prichard Formation. Composed of hornblende, biotite, plagioclase, quartz and opaque minerals (Bishop, 1973 and 1976). Thicker sills are texturally and compositionally zoned; fine-grained diabasic borders grade irregularly into coarse gabbro and quartz-dioritic granophyre, which is concentrated in upper parts of sills. Where exposed, contacts are normally sharp. Some sills disrupt adjacent sedimentary rocks in a manner indicating sedimentary rocks were not lithified at the time of intrusion and probably contained interstitial water (Cressman, 1989). Most intrusions are reasonably concordant, locally stepping only from one bed to another, but some, especially in lower part of Prichard Formation, are clearly discordant. Zircon from a sill near Bonners Ferry, Idaho (Crossport-C sill of Bishop, 1973) gives discordant uranium-lead age of 1,433 Ma (Zartman and others, 1982). Anderson and Davis (1995) regard this age too young, due to probable lead loss. From sills north of the quadrangle, found at approximately the same stratigraphic position, Anderson and Davis (1995) report U-Pb ages of 1,468 Ma. Sears and others (1998) report similar ages from sills southeast of quadrangle. Undated sills above lower Prichard Formation, such as sill in Wallace Formation east of Bonners Ferry, probably represent younger periods of igneous activity

Yp **Prichard Formation**—Interbedded quartzite, siltite, and argillite; color ranges
Ypf from white to pale gray for quartzite, pale to medium gray for siltite, and medium to dark gray for argillite. Lower 60 percent of formation is made up of zones dominated by quartzite interlayered with zones dominated by siltite-argillite couplets. Quartzite-dominated zones are graded and interpreted as turbidites (Bishop and others, 1970), although bottom marks are rare and some zones of thinner quartzite have abundant ripple-drift cross-laminations. Middle part of formation is 1,500 to 1,900 m thick composed mainly of siltite-argillite couplets, much of it microlaminated. This part of formation includes lithology informally termed lined rock by Cressman (1989). Upper part of formation consists of thick-bedded siltite and silty argillite and thin-bedded siltite and argillite. This sequence has irregular bed thicknesses and contains quartzite beds in upper part. Uppermost part includes transition zone into Burke Formation, which at some places outside Bonners Ferry quadrangle is included in Burke Formation. Entire formation contains pyrite or pyrrhotite; highest concentration appears to be in argillite. Oxidation of pyrite and pyrrhotite causes almost all rock surfaces in Prichard Formation to be iron stained. Bed thickness ranges from submillimeter lamination in argillite to over one meter especially in siltite zones. Parallel-planar bedding is by far most common type, but uneven bed thickness is found through much of formation, particularly in uppermost part. Graded bedding is most common sedimentary feature, especially in siltite-argillite couplets. Finely laminated rock, informally termed lined rock, lacks grain-size variation; lined characteristic may represent difference in organic content and sulfide minerals (Huebschman, 1973). Crossbedding and cross-lamination is uncommon in most of formation but is abundant

in uppermost part. Slump folds and matrix-supported breccia found locally. Metamorphic grade and deformation generally low, except north and west of Priest Lake and south of Naples. Except for area south of Naples, Prichard Formation east of Purcell Trench only locally contains small garnets in phillitic argillite. Both local and regional variation in thickness of Prichard Formation is at least partly due to variation in thickness and concentration of sills. Apparent thickness east of Purcell Trench and west of Moyie Fault, including sills, is about 8,500 m (Burmester, 1985) but may include some repetition by faulting. Thickness east of Moyie Fault is less certain. In hanging wall of Newport Fault, thickness of Prichard Formation calculated from outcrop width is 5,400 m. In footwall of Newport Fault, Prichard Formation west of Purcell Trench is too deformed to estimate thickness. Undetected faults are probably present in all sections. In southeastern part of quadrangle, on Slate Ridge and McGinty Ridge, quartz-rich, granophyric-looking, fine-grained rock (Ypf) is probably part of Prichard Formation. This rock lacks bedding but otherwise its appearance is similar to quartzite in Prichard. Unit Ypf composition is 44 percent quartz, 25 percent plagioclase, 17 percent muscovite, 12 percent biotite, and trace of other minerals. Muscovite commonly forms rosettes. Unit Ypf is interpreted to be product of intrusion of subjacent sill into wet sediment. Alternatively, it could be granophyric intrusion (Hahn and others, 1989)

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