GEOLOGIC MAP OF THE CURLEY CREEK QUADRANGLE, BOUNDARY COUNTY, IDAHO, AND LINCOLN COUNTY, MONTANA

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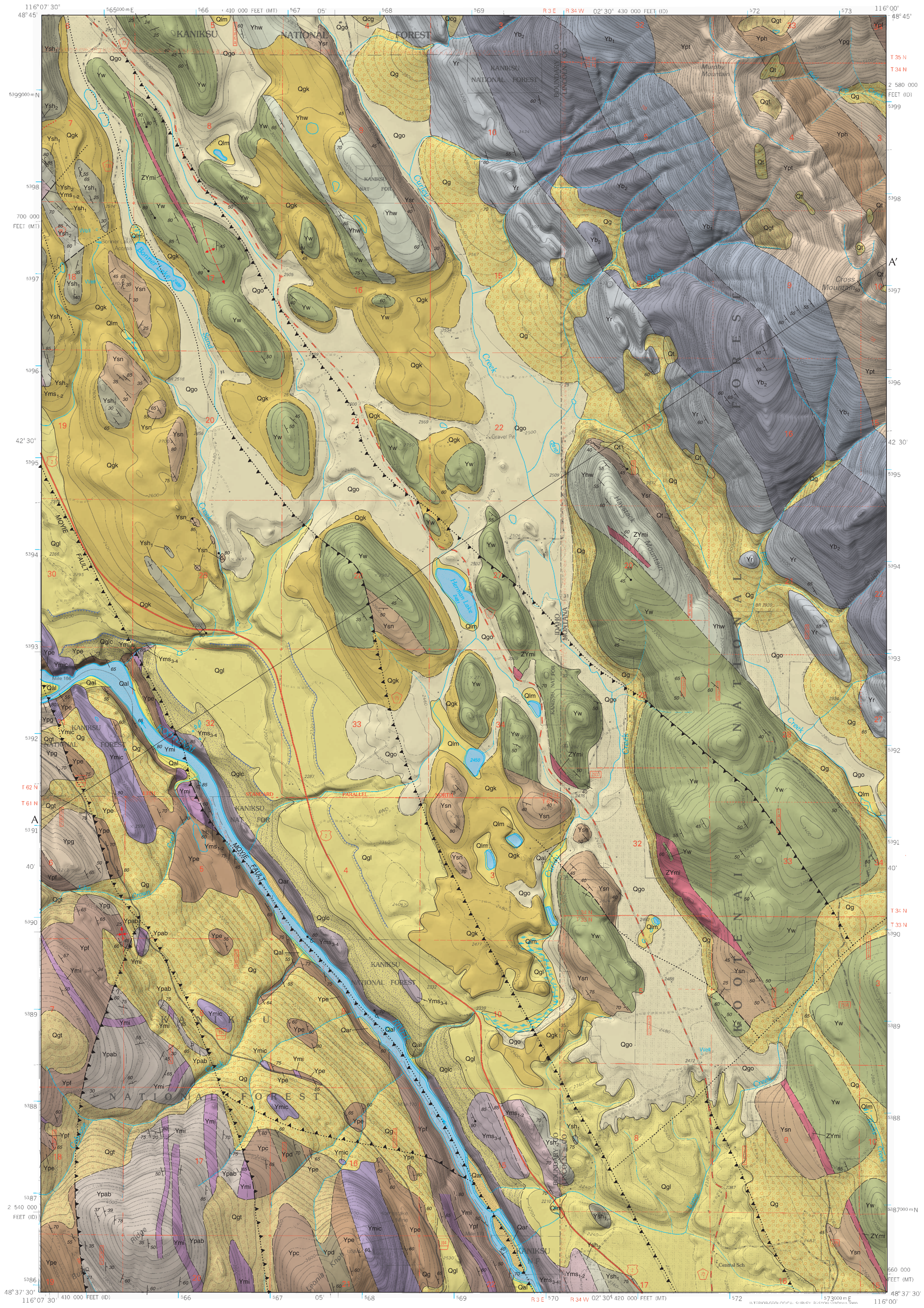
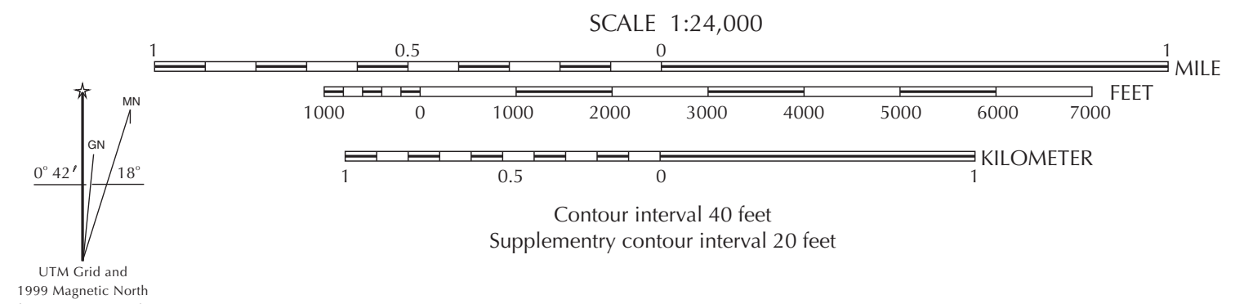
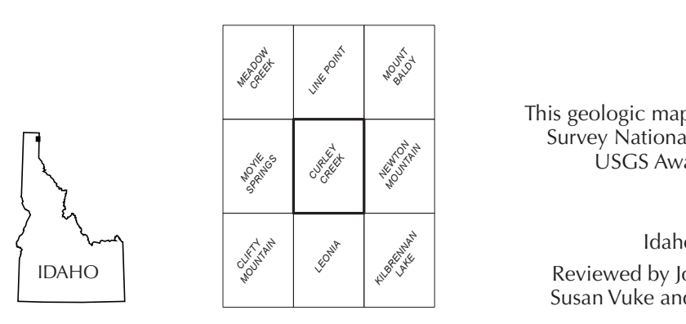
2012



Base Map Credit
Base digitally scanned from 24,000-scale USGS film separates, 1997.
Shaded elevation from 10 m DEM.
Topography compiled 1963. Planimetry derived from imagery taken 1995 and other sources.
Projection: Idaho coordinate system, west zone (Transverse Mercator). 1927 North American Datum.
10,000-foot grid ticks based on Idaho coordinate system, central zone.
1000-meter Universal Transverse Mercator grid ticks, zone 11.



Contour interval 40 feet
Supplementry contour interval 20 feet



QUADRANGLE LOCATION   ADJOINING QUADRANGLES

[1]Idaho Geological Survey
[2]Montana Bureau of Mines and Geology
Field work conducted 2009-2011.
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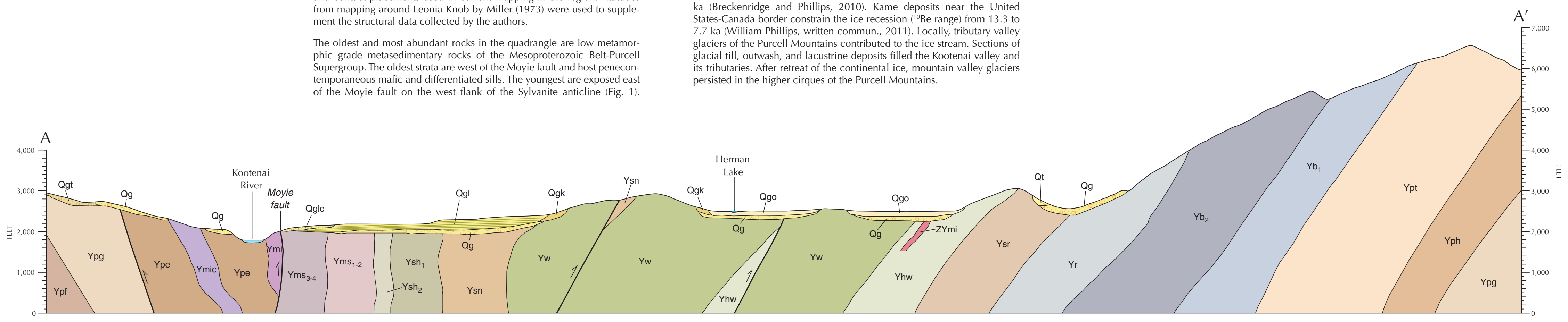
Digital cartography by Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.
Reviewed by John D. Kauffman, Idaho Geological Survey; Susan Vuke and Catherine McDonald, Montana Bureau of Mines and Geology.
Map version 11-16-2012.
PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org.

INTRODUCTION

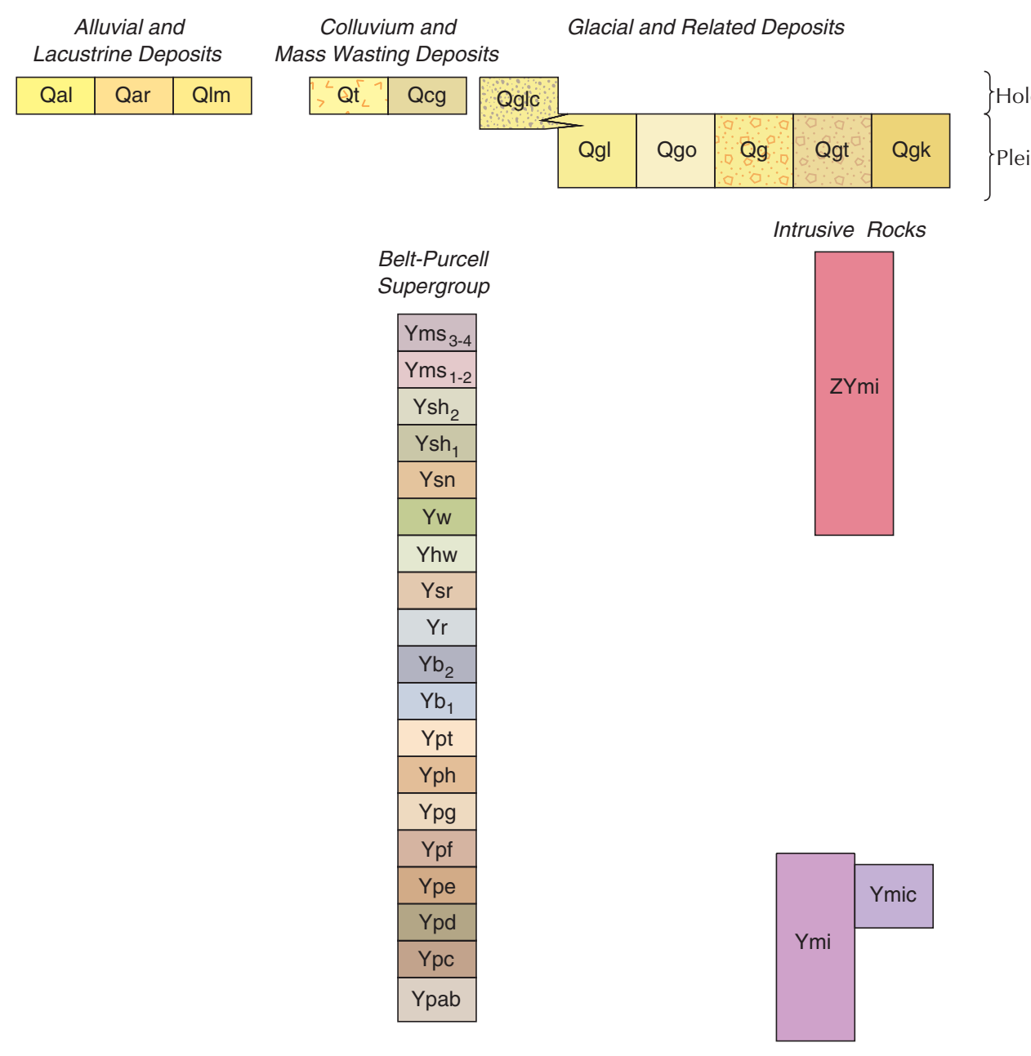
Quaternary deposits on the Curley Creek quadrangle were mapped in 2010-2011 by R.M. Breckenridge. Bedrock was mapped in 2009 and 2011 by R.F. Burmester, R.S. Lewis, M.D. McFadden, and J.D. Lonn to modify previous mapping (Burmester, 1986) for consistency with unit definitions and contact placements used in current mapping in the region. Attitudes from mapping around Leonia Knob by Miller (1973) were used to supplement the structural data collected by the authors.

The oldest and most abundant rocks in the quadrangle are low metamorphic grade metasedimentary rocks of the Mesoproterozoic Belt-Purcell Supergroup. The oldest strata are west of the Moyie fault and host penecontemporaneous mafic and differentiated sills. The youngest are exposed east of the Moyie fault on the west flank of the Sylvanite anticline (Fig. 1).

During Pleistocene glaciations, the Purcell Trench Lobe of the Cordilleran Ice Sheet repeatedly advanced southward from Canada and dammed the north flowing Kootenai River, forming Glacial Lake Kootenai. Cosmogenic ^{10}Be surface exposure ages (mean weighted) constrain the glacial maximum ice limit near the Clark Fork ice dam of Glacial Lake Missoula at 14.1 ± 0.6 ka (Breckenridge and Phillips, 2010). Kame deposits near the United States-Canada border constrain the ice recession (^{10}Be range) from 13.3 to 7.7 ka (William Phillips, written commun., 2011). Locally, tributary valley glaciers of the Purcell Mountains contributed to the ice stream. Sections of glacial till, outwash, and lacustrine deposits filled the Kootenai valley and its tributaries. After retreat of the continental ice, mountain valley glaciers persisted in the higher cirques of the Purcell Mountains.



CORRELATION OF MAP UNITS



SYMBOLS

Contact: dashed where approximately located.

Thrust fault: teeth on upper plate; ball and bar on downthrown side; dashed where approximately located; dotted where concealed.

Fault: dashed where approximately located; dotted where concealed.

Anticline axial trace, arrow indicates direction of plunge; dashed where approximately located; dotted where concealed.

Syncline axial trace, arrow indicates direction of plunge; dashed where approximately located; dotted where concealed.

10 Strike and dip of bedding.

20 Strike and dip of bedding; ball indicates bedding known to be upright.

10 Estimated strike and dip of bedding.

20 Strike and dip of bedding, strike variable.

Strike of vertical bedding.

70 Strike and dip of overturned bedding.

85 Strike and dip of overturned bedding; ball indicates bedding known to be upright.

60 Estimated strike and dip of overturned bedding.

35 Strike and dip of cleavage.

80 Strike and dip of crenulation cleavage.

20 Bearing and plunge of small fold axis.

Terrace escarpment.

Cirque headwall: ticks on glaciated side.

DESCRIPTION OF MAP UNITS

Intrusive rocks are classified according to IUGS nomenclature using normalized values of modal quartz (Q), alkali feldspar (A) and plagioclase (P) on a ternary diagram (Streckeisen, 1976). Mineral modifiers are listed in order of increasing abundance for igneous rocks. Grain size classification of unconsolidated and consolidated sediment is based on the Wentworth scale (Lane, 1947). Bedding thicknesses and lamination type are after McKee and Weir (1963) and Winston (1986). Grain sizes and bedding thicknesses are given in abbreviation of metric units (e.g., dm=decimeter). Unit thicknesses and distances are listed in both metric and English units. Elevations are given in feet only. Multiple lithologies within a rock unit description are listed in order of decreasing abundance. Soil descriptions for Quaternary units are after Chugg and Fosberg (1980) and Weisel (2005).

ALLUVIAL AND LACUSTRINE DEPOSITS

Qar **Active river wash (Holocene)**—Silt, clay, and sand deposits in the active channel and flood plain of the Kootenai River. Most channel substrate represents a modern deposit related to the 1972 completion of Libby Dam upstream in Montana.

Qal **Alluvium (Holocene)**—Alluvial deposits of the Kootenai River and its tributary streams. Moderately sorted to well-sorted silt, sand, and local pebble and cobble gravels. Mostly reworked glacial deposits in the river valley and postglacial colluvium in the surrounding mountains. Schnoorson-Ritz-Farnhampton soils association; typical soils are very deep silty clay loams, silt loams, and mucky silt loams in basins and swales and on low terraces, flood plains, and natural levees. Thickness is several meters to more than 10 m (6 to >30 ft).

Qlm **Lacustrine and mud deposits (Holocene)**—Organic muck, mud, and peat bogs in poorly drained paleoglacial outwash channels, kettles, and scoured bedrock depressions. Interbedded with thin layers of fine sand, silt, and clay. Soils of the Pywell series. Thickness 1-5 m (3-16 ft).

COLLUVIAL AND MASS WASTING DEPOSITS

Qt **Talus (Holocene)**—Blocky and tabular, poorly sorted angular clasts of Belt-Purcell Supergroup rocks form talus deposits below cirque headwalls and cliffs oversteepened by glaciation. Generally no soil development. Thickness varies, usually 3-9 m (10-30 ft).

Qcg **Colluvial deposits derived from glacial materials (Holocene and Pleistocene)**—Silt, sand, and gravel colluvium. Forms debris fans and colluvial aprons along steep valleys and gullies mostly derived from glacial deposits. Includes small unmappable mass movements. Thickness varies, typically 5 m (15 ft).

GLACIAL AND RELATED DEPOSITS

Qglc **Glaciolacustrine deposits and colluvium (Holocene to Pleistocene)**—Mixed deposits of silt, sand, and gravel colluvium, slope wash, and small landslides. Steep slopes of reworked and locally transported *Qgl*. Soils are silt loams of the Wishbone-Crash association. Thickness as much as 10 m (30 ft).

Qgl **Glaciolacustrine deposits (Holocene to Pleistocene)**—Massive to well-bedded and finely laminated clay, silt, and sand deposited in Glacial Lake Kootenai at the northward retreating ice margin in the Purcell Trench. Exhibits well-developed rhythmites and beds of sand and silt with scattered dropstones. Contorted bedding and loading structures are common. This unit forms several prominent terrace levels from an elevation about 2,200 to 2,400 feet; also forms discontinuous terraces in tributary valleys. Mostly well sorted and finely laminated. Overlain by glaciofluvial outwash deposits on terraces and in tributary valleys. Soils are silt loam and silty sandy loams of the Wishbone-Crash association. Exposed thickness as much as 150 m (500 ft).

Qgo **Outwash deposits, undivided (Holocene and Pleistocene)**—Bouldery and sandy gravels. Moderately sorted and rounded pebbles and cobbles. Includes small unmappable deposits of alluvium. Soils are sandy loams and loamy sands of the Selle-Elmira Association. Maximum thickness about 20 m (60 ft).

Qg **Till and kame deposits (Pleistocene)**—Mapped where *Qgt* and *Qgk*, described below, are not separable at the map scale.

Qgt **Till deposits (Pleistocene)**—Dense silt, pebble, and cobble till with boulders deposited by mountain valley glaciers. Poorly stratified till of locally derived sources forms moraines with interbedded proglacial deposits. Includes kame terraces and some outwash in valleys. Soils include silt loams and gravelly silt loams of the Pend Oreille-rock outcrop and the Stien-Pend Oreille associations. Thickness varies, 1-30 m (3-100 ft).

Qgk **Kame deposits (Pleistocene)**—Poorly stratified and compact silty to sandy boulder lodgment till; locally includes ground moraine and some interbedded proglacial and ice contact and outwash deposited by the Purcell Trench ice lobe. Soils include silt loams and gravelly silt loams of the Stien-Pend Oreille association. Thickness varies; may exceed 50 m (160 ft).

INTRUSIVE ROCKS

ZYmi **Mafic intrusive rocks, undivided (Neoproterozoic or Mesoproterozoic)**—Fine- to medium-grained diorite or gabbro. Generally greenish where fresh. Contains calcite, probably as product of greenschist facies metamorphism. Mapped separately from Moyie sills because of occurrence in the Piegan Group. May be coeval with the Purcell lava (rhyolite about 55 km (35 mi) east-northeast dated at 1.443 Ga; Evans and others, 2000), or possibly with a sill complex that trends toward this area from the southeast (760 Ma; Burtis and others, 2008).

Ymi **Mafic intrusive rocks, undivided (Mesoproterozoic)**—Fine- to medium-grained, rarer coarse-grained, hornblende gabbro and quartz diorite. Variants have laths of plagioclase, quartz as large blue grains, or quartz in granophyre. Grain size, quartz, and mafic mineral content vary between intrusions and commonly within single bodies, both along and across strike. Medium-grained quartz diorite and biotite granophyre differentiates most common at or near tops of sills, but also occur separately. Occurs as Moyie sills in *Ypf* and lower units; generally concordant, but some laterally pinch and swell, include rafts of country rock, branch into multiple sills, end abruptly, or gradually pinch out (Bishop, 1976). Although sills lower and higher in the Aldridge Formation (Prichard correlative in Canada) are similar in chemistry (Anderson and Goodfellow, 2000), they seem to have intruded in at least two separate events. Early intrusions were at shallow levels closely following sedimentation of the Lower Aldridge (Höy and others, 2000; Gorton and others, 2000; Cressman, 1989; Sears and others, 1998; Poage and others, 2000). Higher intrusions with chilled margins and contact aureoles must have intruded consolidated rock at a later time. Age of older sills is probably close to U-Pb dates on zircons from near Kimberley, British Columbia, about 120 km (75 mi) north (1.468 Ga; Anderson and Davis, 1995), and from Plains, Montana, about 180 km (110 mi) south-southeast (1.47 Ga; Sears and others, 1998).

Ymic **Mafic intrusive rocks, Crossport C sill (Mesoproterozoic)**—Fine- to coarse-grained hornblende gabbro, quartz diorite, and hornblendite. Finer grained varieties are typically near bottom and top of sill; quartz-rich varieties more common near top. Hornblendite may be local cumulate below quartz-rich differentiates. This sill is fault repetition of the middle or "C" sill of Bishop (1973, 1976) defined in the Moyie Springs quadrangle to the west. Thickness 210 m (700 ft) near west map edge and about 275 m (900 ft) near south edge.

BELT-PURCELL SUPERGROUP

Missoula Group

The Missoula Group includes all Belt units above the Piegan Group as recently redefined by Winston (2007). It is similar to the Ravalli Group in that it is characterized as a clastic wedge (quartzite, siltite, and argillite), but had a different source (Ross and Villeneuve, 2003). Only the lowest three formations are mapped here.

Mount Shields Formation (Middle Proterozoic)—Quartzite, siltite, argillite, and dolomite. Although highly varied lithologically, formation is characterized by maroon and green colors, domal stromatolites, and abundant and varied sedimentary structures.

Yms_{3-4} **Mt. Shields members 3 and 4 (Mesoproterozoic)**—Siltite, argillite, and dolomite. Lower part is dominated by green siltite that contains partings of green and maroon argillite. Polygonal mudcracks, mudchip breccias, oscillation ripple marks, and salt casts are common, especially in maroon rocks. Bedding generally thickens upward, but thin, light to dark green siltite and argillite couplets are scattered throughout. Carbonate rocks and carbonate-bearing rocks are more common toward the top where "boxwork" carbonate is formed from recessive weathering of dolomite relative to quasi-orthogonal silica veinlets. Dolomite is blue-gray where fresh and weathers light brown to orange. Upper contact is a fault; minimum thickness from outcrop width in southern part of quadrangle is 360 m (1,200 ft). Corresponds closely to members 3 and 4 of Harrison and others (1992).

Yms_{1-2} **Mt. Shields members 1 and 2 (Mesoproterozoic)**—Red, pink, green, and gray quartzite, green and red siltite and argillite, and minor carbonate. Green and lighter colors are more common toward base. Quartzite, in 0.3 to rarely 1.0 m beds, is fine grained, mostly flat laminated, but also cross laminated, and contains potassium feldspar well in excess of plagioclase. Diffuse, nonresistant brown wisps of carbonate within the quartzite of upper part of unit average a few centimeters in thickness and 10-15 cm in length. Commonly rippled tops of the quartzite beds have thin red argillite drapes. Siltite and argillite occur as graded and lenticular couplets and microlaminae. Both red and green couplets have dewatering structures, mudcracks, and mudchip breccias. Green strata may have more disrupted zones but red strata have larger mudchips. Top approximately 35 m (115 ft) contains several 1-5 dm (rarely 10 dm) layers of purple, buff-weathering low domal stromatolites. Stromatolites are as high as 30 cm and 1 m across, with bases of oolite and coarse well-rounded quartz grains. Upper contact placed above highest stromatolite. Stromatolites well exposed east side of Highway 2, section 15, and along railroad cut in the southern part of section 32. Map pattern thickness 350 m (1,150 ft) possibly affected by faulting.

Shepard Formation (Mesoproterozoic)—Occupies same stratigraphic level as the upper two units of the Wallace Formation mapped to the south of quadrangle (Harrison and Jobin, 1963; Lewis and others, 1999, 2000, 2002). Named Shepard Formation here because it is not markedly different from the Shepard Formation at its type locality and is separated from the carbonate-bearing pinch-and-swell strata typical of the Wallace Formation as found near Wallace, Idaho, by carbonate-free dark laminated strata (*Ysn*). Subdivision follows Lemoine and Winston (1986) and Burmester (1986).

Ysh_2 **Shepard Formation, member 2 (Mesoproterozoic)**—Microlaminated to laminated dark gray to black argillite, dark olive-green to white weathering siltite, and very fine-grained white quartzite. Laminations commonly contorted, rarely cracked. Contortions attributed to soft-sediment deformation. Siltite and quartzite beds are as thick as 5 cm. Upper contact placed at base of lowest purple argillite or quartzite of Yms_{1-2}. Best exposed northeast of Highway 2 in northeast corner of section 15 below Yms_{1-2}. Thickness about 120 m (400 ft). Previously also mapped as argillite of Half Moon Lake (Miller and Burmester, 2004).

Ysh_1 **Shepard Formation, member 1 (Mesoproterozoic)**—Tan- and brown-weathering, uneven couplets of green siltite and carbonate-bearing light green argillite. Includes intervals of unevenly laminated dark green siltite and light green argillite, and white quartzite. Some argillite tops are microlaminated. Nonresistant horizontal limestone pods usually weathered out. Contorted chip layers and soft-sediment deformation, and centimeter-scale loads and flames are typical. Siltite and quartzite are commonly ripple drift and cross-laminated in beds 2-5 cm thick, or occur as starved ripples that form lenticular bedding. Upper contact placed at lowest black argillite of Ysh_2. Best access in Highway 2 roadcuts, sections 29 or 17. Thickness uncertain because of faulting and transposition of bedding where folding intense, but probably less than 500 m (1,500 ft).

Snowslip Formation (Mesoproterozoic)—Divided into three members where mapped to the south as argillite of Howe Mountain (Burmester and others, 2006); undivided where mapped as lower part of upper Wallace Formation farther south (e.g. Lewis and others, 1999, 2000). Total thickness to south about 900 m (3,000 ft). Discontinuous exposure and faulting preclude accurate determination of thickness or subdivision within this quadrangle.

Ysn **Snowslip Formation (Mesoproterozoic)**—Dark green siltite and light green argillite in graded and nongraded couplets, green siltite and dark gray argillite couplets, purple siltite and argillite couplets, and green to gray siltite. Lower part is predominately green couplets with a purple zone near the middle. All characteristically have mud and dewatering cracks. Middle part consists of planar laminated couplets and microlaminae of greenish-gray- to white-weathering siltite and dark gray to black argillite with millimeter-scale bumps on bedding surfaces. Similar plane-parallel lamination is widespread in middle of unit elsewhere (Burmester, 1986; Burmester and others, 2006; Lewis and others, 1999). Upper part is similar to lower except it lacks purple beds, contains minor carbonate, and perhaps more sulfides. Upper contact placed below concentration of carbonate-bearing lenticular couplets or thick white quartzite of Ysh_1. Most continuous section is southwest of Bonner Lake in northeast corner of section 19. Minimum thickness based on outcrop width is 550 m (1,800 ft).

Piegan Group

The Piegan Group was resurrected by Winston (2007) to provide group-level continuity across the Belt basin. It includes only the Helena and Wallace formations. Excluded from the Wallace are upper members mapped to the south in the past (e.g., Harrison and Jobin, 1963; Lemoine and Winston, 1986; Lewis and others, 1999, 2000, 2002). Because the carbonate-rich strata below the Wallace in most of Idaho are appreciably different from those in the Helena Formation's new reference section in Glacier National Park, we distinguish those strata as the western facies of the Helena.

Yw **Wallace Formation (Mesoproterozoic)**—Carbonate-bearing light gray to white siltite and quartzite and dark gray to black argillite. Some siltite and quartzite are at bases of pinch-and-swell couplets and couples graded to dark argillite tops. Argillite caps characteristically contain ptygmatically folded siltite- or quartzite-filled cracks that taper downward. On bedding plane surfaces, cracks are generally discontinuous and sinuous, occurring as isolated parallel or three-pointed stars, with concave-up argillite between. Less diagnostic components are dark bluish gray silty dolomite in beds 1-5 dm thick with molar tooth calcite ribbons, uneven graded couplets of pale green siltite and calcitic argillite, and white, pyritiferous, very fine-grained calcitic quartzite in 1-5 dm beds, some with hummocky cross stratification. Matrix-supported breccias, with flat clasts 5-20 mm thick and 2-10 cm long in sand, and smaller, irregular ones in mud, are near base at east edge of map. Upper contact placed above highest black-capped pinch-and-swell couplets. Best exposed northeast of Bonner Lake. Thickness based on map width is 440 m (1,450 ft), less than that to the south (790 m, 2,600 ft; Burmester and others, 2004). Zircons from a tuff near contact with Snowslip Formation about 170 km (105 mi) east yielded a U-Pb date of 1.454 Ga (Evans and others, 2000).

Yhw **Helena Formation, western facies (Mesoproterozoic)**—Pale green carbonate-bearing siltite and argillite. Green siltite and argillite laminae and nongraded couplets at base are commonly disrupted by mudcracks and centimeter-wide dewatering cracks. Overall, unit is coarser grained than *Ysr*. Dolomite is typically disseminated in tabular beds of tan-weathering greenish siltite and less so in argillite; calcite is concentrated in nonresistant horizontal centimeter-scale pods and vertical ribbons (molar tooth structure). Carbonate is more common toward top. Decimeter-scale gray limestone beds may have been stromatolites. Includes zones of carbonate-free laminated to thin-bedded green cross-laminated siltite with lighter green argillite tops and rare graded couplets. Some parting surfaces are rippled; lenticular nonparallel bedding is attributed to ripple and starved ripple lamination. Siliciclastic to carbonate cycles typical of Helena were not recognized, perhaps due to discontinuous exposure. Upper contact, placed at lowest occurrence of black argillite-capped pinch-and-swell couplets, may be too high in places where solution of calcitic black caps of *Yw* hinders identification of pinch-and-swell couplets. Best exposed along crest of Haystack Mountain. Thickness approximately 600 m (2,000 ft). Unit corresponds to the Helena and Empire formations to the east (Harrison and others, 1992).

Ravalli Group

The Ravalli Group that crosses the northeast quadrant of the map is only slightly thicker than documented to the southeast (Cressman and Harrison, 1986) and south-southwest (Burmester and others, 2007). Although cosets of thick sets of quartzite used to define the Revett elsewhere (Hayes, 1983; Hayes and Einaudi, 1986) are rarely observed, Revett is mapped on the east side of the Sylvanite anticline, Fig. 1, (Cressman and Harrison, 1986) and correlated with the middle Creston north of the border where copper-silver-cobalt mineralization is similar to that in the Revett to the south (Hartlaub, 2009). Revett mapped here as the swath of quartzite-rich strata below more typical St. Regis Formation may correspond to the upper Revett mapped elsewhere, and the upper Burke (Yb_2) may correspond to the lower Revett.

Ysr **St. Regis Formation (Mesoproterozoic)**—Purple and green siltite, argillite, and quartzite. Lower strata are entirely shades of purple with lighter siltite and darker argillite couplets that are uneven to lenticular and commonly mudcracked. Includes discrete layers of thin mudchips 1-3 cm thick. Green lithologies, more common toward the top, include dark green siltite and lighter green argillite in wavy couplets and couples with rare 1 mm-thick brown dolomitic wisps, pale green tabular very fine-grained quartzite beds (2-5 cm, rarely 10-20 cm) with green argillite caps, and green argillite 5-20 cm thick. Dolomite increases upward in millimeter-thick siltite laminae and in pale green siltite layers. Upper contact placed above highest mudcracked and mudchip-bearing purple siltite and argillite; may be placed too low where highest purple obscured. Best exposed in cliffs on northeast side of Haystack Mountain. Minimum thickness near north map edge is 275 m (900 ft).

Yr **Revett Formation (Mesoproterozoic)**—White and greenish-gray quartzite, pale purple, gray, and green siltite, and darker gray or purple argillite. Very fine-grained feldspathic quartzite is commonly in 1-5 dm, rarely 1 m, tabular beds that contain parallel, cross, and convolute laminations. Some thicker beds have large trough cross bedding and scoured bases. Tops are rippled, capped with mudcracked argillite, or missing where beds are amalgamated. Siltite is similar to quartzite and occurs as bases of couplets graded to argillite tops. Mudcracks and chips are distributed throughout. Contains visible magnetite octahedra as reported to the east (Harrison and others, 1992). Poor exposure in area is attributed to fracturing of brittle quartzite into small pieces during deformation. Upper contact placed above highest massive white quartzite. Discontinuously exposed low on the southwest slope of Cross Mountain. Thickness about 450 m (1,500 ft).

Burke Formation (Mesoproterozoic)—Siltite, argillite, and quartzite. Subdivided into two members on this map based on bedding characteristics and sedimentary structures.

Yb_2 **Burke Formation, member 2 (Mesoproterozoic)**—Green to gray-green siltite, purple and green argillite and siltite, and purple laminated quartzite. Lower part is dominantly 10-20 cm thick siltite beds, typically with macroscopic magnetite octahedra. Slabby partings are commonly along 1-2 mm thick skins of dark green and some lighter green argillite. Sedimentary features include cross lamination, ball-and-pillow structure, rare convolute lamination, and rare thin mudchips. Purple colors, mudcracks, mudchips, and quartzite increase upward. Quartzite is very fine grained with planar and rarer cross laminae enhanced by purple hematite concentrations. Purple-banded or zebra-striped quartzite in beds 10-30 cm thick occurs near top. Upper contact placed at base of lowest thick white quartzite. Best exposed southwest of Cross Mountain. Thickness there approximately 600 m (2,000 ft).

Yb_1 **Burke Formation, member 1 (Mesoproterozoic)**—Green to gray-green siltite and argillite, and gray to white quartzite. Lower part is dominantly slabby and platy parting 10-20 cm thick tabular beds of tan- to olive-drab-weathering, greenish-gray siltite, commonly with flat laminations. Magnetite octahedra are as large as 1 mm. Minor carbonate near base occurs as very thin beds and scattered nodules less than 1 cm in length. Light gray, very fine-grained quartzite increases upward, most commonly as bases of undulating couplets and couples that grade up through gray siltite with rare argillite skins. Upper contact placed at lowest occurrence of purple mudcracked argillite and quartzite. Best exposed southwest of Cross Mountain. Thickness there approximately 500 m (1,600 ft).

Lower Belt

The Prichard Formation consists of the lowest strata of the Belt-Purcell Supergroup. It is equivalent to the Aldridge Formation in Canada.

Prichard Formation (Mesoproterozoic)—Dark to light gray siltite, black, gray, and white argillite, gray to white feldspathic quartzite, and white quartzite. Siltite is typically rusty weathering and planar laminated with black or, rarely, white graded or nongraded argillite tops. Conspicuous bar code-like patterns in the middle of the Prichard, formed by alternating dark and light siltite, persist regionally (Huebschman, 1973) and have been used as markers for correlation by Cominco (Hamilton and others, 2000). Rusty nature of outcrop is due to weathering of abundant sulfides, commonly pyrrhotite. Dominant lamination style and concentration of sulfides vary between members. Quartzite is light weathering and averages about 60 percent quartz, 20 percent plagioclase; the rest is mostly white micas and biotite (Cressman, 1989). Previous mapping in this area and to the east (Cressman and Harrison, 1986) subdivided only the top of the Prichard. Here, we apply alphabetic member assignments of Cressman (1989). Presence versus absence of sedimentary structures recording strong currents or soft-sediment deformation are lithologic criteria used to distinguish adjacent members, but assigning quartzite packages with similar characteristics to different members was facilitated by release of mapping by Cominco with control based on "markers" (Michael Zientek, written commun., 2003). These markers served for the upper units down through *Ype*. Locations of some of these markers (Glombick and others, 2010) aided matching contacts across the international border. Cominco did not map below *Ype*, so our attempt to identify lower units is based partly on correlation of the lower-middle Aldridge contact with the top of a concentration of sills just north of the border (Glombick and others, 2010), or the *Ypb-Ypc* contact (Michael Zientek, written commun., 2003) and on the subdivisions of Finch and Baldwin (1984).

Ypt **Prichard Formation, transition member (Mesoproterozoic)**—Gray to greenish gray to white siltite, dark gray or black argillite, and white quartzite. Tops of siltite and argillite couplets typically have discontinuous cracks that appear spindle shaped in plan view and ptygma-like in section. Argillite also occurs as massive beds 10-50 cm thick. Siltite beds 3-10 cm thick are cross laminated or have internal grading from light to dark gray where internal structure is visible; parting more commonly platy than slabby. Brown-weathering carbonate as 1 cm layers and pods are low in the section. Siltite beds increase upward in relative abundance and become olive drab where weathered. Quartzite is fine grained and characterized by dark planar laminations, as well as common ripple and larger low-angle cross laminations, hummocky cross lamination, small "dish" structures, and scattered load structures 5-15 cm in depth. Dark specs within siltite appear to be biotite low in unit, but magnetite toward the top. Upper contact placed above highest recognized dark gray argillite tops, where lighter greenish gray argillites of Yb_1 dominate. Forms ridgeline in northeast corner of map. Thickness 700 m (2,300 ft). Previously mapped here (Burmester, 1986) and immediately to the east (Cressman and Harrison, 1986) as "transition zone" into overlying Burke Formation, whereas elsewhere included in Burke (Cressman, 1985) or Creston Formation (Brown and others, 1994).

Yph **Prichard Formation, member h (Mesoproterozoic)**—Laminated gray siltite and black argillite couplets to microlaminated black argillite with white siltite "lines." Includes minor brownish siltite and light-weathering quartzite. Laminae and microlaminae are characteristically very even and continuous. Talus is typically platy. Also forms large rounded outcrops and boulders. Weathers with a distinct rusty veneer. Siltite beds are 3-10 cm thick with slabby parting; quartzite beds are 3-5 dm thick and occur in middle of unit. Includes rare 2-10 cm thick calcareous silty laminae that weather recessively. Upper contact placed below lowest occurrence of white quartzite and pinch-and-swell siltite and argillite couplets of overlying *Ypt*. Poorly exposed in northeast corner of map. Thickness about 500 m (1,600 ft). Nicknamed the "lined unit" of the Prichard Formation and equivalent to the upper Aldridge Formation in Canada.

Ypg **Prichard Formation, member g (Mesoproterozoic)**—Green-gray siltite, dark gray argillite, and gray to white feldspathic quartzite. Siltite beds are even-parallel laminated, some graded to dark gray argillite, which also occurs separately. Fine- to very fine-grained quartzite forms 1-5 dm, rarely thicker, beds. Some quartzite beds have dark argillite tops, others have ripple cross lamination and rippled tops. Top not exposed in quadrangle; elsewhere placed below thick interval of flat-laminated dark siltite and argillite. Best exposed southwest of Kootenai River along western edge of map in section 6. Thickness about 500 m (1,600 ft).

Ypf **Prichard Formation, member f (Mesoproterozoic)**—Rusty-weathering, tabular, dark and light gray siltite, darker gray argillite, and minor lighter quartzite. Siltite is commonly in tabular, structureless, or even-parallel laminated beds 1-20 cm thick, with slabby to platy parting. Quartzite is very fine to fine grained and feldspathic in tabular beds 6-20 cm thick with tops graded to siltite or dark argillite. Bases of some beds are slightly uneven from loading into finer grained material. Carbonate concretions 30-50 cm in diameter are common in thicker beds. Upper part is mostly dark, pyrrhotite-bearing siltite with marker-bed-like color layering common. Hosts mafic sills "D" and "E" of Bishop (1973, 1976). Upper contact placed below rippled, cross-laminated, and unevenly bedded strata of *Ypg*. Best exposed south of Kootenai River in Caboose Creek drainage, southwestern edge of map. Thickness possibly 900 m (3,000 ft); uncertainty due to fault truncation and folding of upper part. Previously subdivided following Finch and Baldwin (1984) into lower member with more quartzite and upper member with more argillite (Burmester, 1986); upper part mapped to the east as argillite member of the Prichard Formation (Cressman and Harrison, 1986).

Ype **Prichard Formation, member e (Mesoproterozoic)**—Light gray- to white-weathering siltite, and feldspathic quartzite with darker argillite. Light gray, light-weathering siltite dominates over darker, rusty-weathering siltite and light gray, light-weathering, very feldspathic fine-grained quartzite. Some beds are parallel laminated, but many exhibit features of current traction such as trough cross bedding, ripple and ripple drift cross lamination, rippled tops, and inclusion in quartzite beds of rectangular rip-up clasts 5-15 cm long. Soft-sediment deformation and convolute lamination are common; centimeter-scale load casts and ball-and-pillow structures locally abundant. Carbonate concretions 5 cm to 3 dm across appear as dark masses or spots, or brown cavities. Some quartzite beds that are coarser grained and less feldspathic than typical of the Prichard contain rounded medium quartz grains, especially concentrated at bed bases. Some quartzites grade up to or are overlain by laminated siltite and microlaminated argillite. Quartzite-rich sections commonly have cosets of 20-50 cm thick beds with no or very little intervening argillite. These form clear ribs and talus slopes. Hosts sill "C" of Bishop (1973, 1976). Upper contact placed above highest zone of quartzite with abundant current features and below thick section of uniformly parallel-laminated rusty-weathering siltite. Best but poorly exposed on Leonia Knob, southern edge of map. Thickness approximately 1,200 m (3,600 ft) including 275 m (900 ft) of *Ymic*.

Ypd **Prichard Formation, member d (Mesoproterozoic)**—Dark gray siltite, dark gray argillite, and white-weathering gray quartzite. Siltite, and siltite and argillite couplets are predominantly even and parallel laminated to microlaminated and rusty weathering. Less common are intervals of white, very fine- to fine-grained quartzite in rarely amalgamated beds, or rusty-weathering siltite. Exposure generally poor and discontinuous, with quartzite commonly over-represented in float. Upper contact placed at lowest occurrence of current-laminated siltite and quartzite below *Ymic*. Poorly exposed over Leonia Knob. Thickness uncertain due to poor exposure of contacts, but probably 200-500 m (600-1,600 ft).

Ypc **Prichard Formation, member c (Mesoproterozoic)**—Light-weathering quartzite, darker siltite, and rusty-weathering unevenly laminated, dark gray siltite and argillite couplets. Fine-grained to rare medium-grained quartzite similar to that of *Ype* but in thinner packages is scattered throughout. Some beds have ripple- and cross-lamination, coarser grains at bases and gradation to siltite at tops. Circular brown spots as large as 6 cm diameter with alteration "halos" probably formed from concentrations of manganiferous carbonate. Upper contact placed above set of quartzite beds and below interval of more evenly laminated, rustier weathering siltite and argillite. Mapped over Leonia knob but base not exposed. Minimum thickness 550 m (1,800 ft).

Ypab **Prichard Formation, members a and b (Mesoproterozoic)**—Dark, rusty-weathering siltite and argillite, and minor white-weathering quartzite. Argillite and fine-grained siltite have high sulfide content with parallel lamination dominant. Coarse-grained siltite and fine-grained quartzite as thick as 40 cm, with rippled surfaces and cross lamination may be at tops of coarsening and thickening sequences. More commonly, occur as 1 cm thick beds with ripple cross lamination. Some thicker beds include rectangular clasts; others have loads into underlying argillite and wisps of black argillite at bases. Locally sericitic, with finer grained material metamorphosed to fine-grained schist. Also locally highly fractured, bleached, and orange stained.

STRUCTURE

The major structure in this quadrangle is the Moyie fault. It is characterized regionally as an east-vergent thrust and juxtaposes older rocks on the west (hanging wall) against younger rocks on the east, consistent with this interpretation. However, strata of the hanging and foot walls face each other, giving the impression that the fault occupies a syncline. Support for a synclinal fold geometry comes from existence of a slightly east-verging, southward-plunging syncline west of the Moyie fault south of the map, Fig.1, (Miller and Burmester, 2004) and an open, northward-plunging syncline north of the international border (Brown and others, 1995; Brown, 1998). One hypothesis is that these are remnants of a syncline that was paired with the Sylvanite anticline to the east before further contraction was accommodated by faulting. This situation is consistent with the interpretation that the Moyie fault cut down section into the Sylvanite anticline (Harrison and Cressman, 1993), so must be younger. However, in the northeast quadrant of section 5, the Moyie fault and overturned Yms_{1-2} stromatolites dip steeply east, not the attitude expected of a thrust fault. This configuration is most easily explained if the fault and adjacent beds were folded as part of the west limb of the Sylvanite anticline as it continued or renewed growth after or during thrust faulting. Other structures are an east-side-up fault west of the Moyie fault that repeats part of the Prichard section, and numerous faults to the east that cut out or repeat parts of the section there.

REFERENCES

Anderson, H.E., and D.W. Davis, 1995, U-Pb geochronology of the Moyie sills, Purcell Supergroup, southeastern British Columbia: Implications for the Mesoproterozoic geological history of the Purcell (Belt) basin: Canadian Journal of Earth Sciences, v. 32, no. 8, p. 1180-1193.
Anderson, H.E., and W.D. Goodfellow, 2000, Geochemistry and isotope chemistry of the Moyie sills: Implications for the early tectonic setting of the Mesoproterozoic Purcell basin, *in* J.W. Lydon, Trygve Höy, J.F. Slack, and M.E. Knapp, eds., The Geological Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 302-321.
Anderson, H.E., and Trygve Höy, 2000, Fragmental sedimentary rocks of the Aldridge Formation, Purcell Supergroup, British Columbia, Chapter 14, *in* J.W. Lydon, Trygve Höy, J.F. Slack, and M.E. Knapp, eds., The Geological Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 259-271.
Bishop, D.T., 1973, Petrology and geochemistry of the Purcell sills in Boundary County, Idaho, *in* Belt Symposium, Volume 2: Idaho Bureau of Mines and Geology Special Publication, p. 16-66.
Bishop, D.T., 1976, The petrology and geochemistry of the Purcell sills, Boundary County Idaho and adjacent areas: University of Idaho Ph.D. dissertation, 147 p.
Breckenridge, R.M., and W.M. Phillips, 2010, New cosmogenic 10Be surface exposure ages for the Purcell Trench lobe of the Cordilleran Ice Sheet in Idaho: Geological Society of America Abstracts with Programs, v. 42, no. 5, p. 309.
Brown, D.A., 1998, Geological compilation of the Yahk (east half) and Yahk River (west half) map areas, southeastern British Columbia: British Columbia Ministry of Energy and Mines, Minerals Division, Geological Survey Branch, Geoscience Map 1998-2, 1:50,000 scale.
Brown, D.A., J.A. Bradford, D.M. Melville, A.S. Legun and D. Anderson, 1994, Geology and mineral deposits of Purcell Supergroup in Yahk map area, southeastern British Columbia (82F/1), *in* B. Grant and J.M. Newell, eds., Geological Fieldwork 1993: A Summary of Field Activities and Current Research: British Columbia Ministry of Energy, Mines and Petroleum Resources Paper 1994-1, p. 129-151.
Brown, D.A., J.A. Bradford, D.M. Melville, and P. Stinson, 1995, Geology of the Yahk map area, southeastern British Columbia (82F/1): British Columbia Ministry of Energy, Mines and Petroleum Geological Survey Branch Open File 1995-14, scale 1:50,000.
Burmester, R.F., 1986, Preliminary geologic map of the Leonia area, Idaho and Montana: U.S. Geological Survey Open-File Report 86-554, 13 p., scale 1:48,000.
Burmester, R.F., R. M. Breckenridge, R.S. Lewis, and M.D. McFadden, 2004, Geologic map of the Clark Fork quadrangle, Bonner County, Idaho: Idaho Geological Survey Digital Web Map 25, scale 1:24,000.
Burmester, R.F., R.M. Breckenridge, M.D. McFadden, and R.S. Lewis, 2006, Geologic map of the Derr Point quadrangle, Bonner and Shoshone counties, Idaho: Idaho Geological Survey Digital Web Map 59, scale 1:24,000.
Burmester, R.F., R.S. Lewis, M.D. McFadden, R.M. Breckenridge, D.M. Miller, and F.K. Miller, 2007, Geological Map of the Cocolalla quadrangle, Bonner County, Idaho: Idaho Geologic Survey Digital Web Map 91, scale 1:24,000.
Burtis, E.W., J.W. Sears, and K.R. Chamberlain, 2007, Age and petrology of Neoproterozoic intrusions in the northern Rocky Mountains, U.S.A.: correlation with the Gunbarrel magmatic event, *in* P.K. Link, and R.S. Lewis, eds., Proterozoic Geology of Western North America and Siberia: SEPM (Society for Sedimentary Geology) Special Publication No. 86, p. 175–191.
Chugg, J.C., and M.A. Fosberg, 1980, Soil survey of Boundary County, Idaho: United States Department of Agriculture Soil Conservation Service and United States Department of the Interior Bureau of Indian Affairs in cooperation with University of Idaho College of Agriculture Idaho Agricultural Experiment Station, 75 p.
Cressman, E.R., 1985, The Prichard Formation of the lower part of the Belt Supergroup, Proterozoic Y, near Plains, Sanders County, Montana: U.S. Geological Survey Bulletin 1553, 64 p.
Cressman, E.R., 1989, Reconnaissance stratigraphy of the Prichard Formation (Mesoproterozoic) and the early development of the Belt basin, Washington, Idaho, and Montana: U.S. Geological Survey Professional Paper 1490, 80 p.
Cressman, E.R., and J.E. Harrison, 1986, Geologic map of the Yaak River area, Lincoln County, northwest Monatana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1881, scale 1:48:000.
Evans, K.V., J.N. Aleinikoff, J.D. Obradovich, and C.M. Fanning, 2000, SHRIMP U-Pb geochronology of volcanic rocks, Belt Supergroup, western Montana; evidence for rapid deposition of sedimentary strata: Canadian Journal of Earth Sciences, v. 37, no. 9, p. 1287-1300.
Finch, J.C., and D.O. Baldwin, 1984, Stratigraphy of the Prichard Formation, Belt Supergroup, *in* S.W. Hobbs, ed., The Belt: Abstracts with Summaries, Belt Symposium II, 1983: Montana Bureau Mines and Geology Special Pub. 90, p. 5-7.
Glombick, P., D.A. Brown, and R.F. MacLeod (compilers), 2010, Geology, Yahk, British Columbia: Geological Survey of Canada, Open File 6153, scale 1:50,000.
Gorton, M.P., E.S. Schandl, and Trygve Höy, 2000, Mineralogy and geochemistry of the Middle Proterozoic Moyie sills in southeastern British Columbia, *in* J.W. Lydon, Trygve Höy, J.F. Slack, and M.E. Knapp, eds., The Geological Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 322-335.
Hamilton, J.M., R.G. McEachern, and O.E. Owens, 2000, A history of geological investigations at the Sullivan deposit, *in* J.W. Lydon, Trygve Höy, J.F. Slack, and M.E. Knapp, eds., The Geological Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 4-11.
Harrison, J.E., and E.R. Cressman, 1993, Libby thrust belt of northwestern Montana and its implications to regional tectonics: U.S. Geological Survey Professional Paper 1524, 47 p.
Harrison, J.E., and D.A. Jobin, 1963, Geology of the Clark Fork quadrangle, Idaho-Montana: U.S. Geological Survey Bulletin 1141-K, p. 1-38.
Harrison, J.E., E.R. Cressman, and J.W. Whipple, 1992, Geologic and structural maps of the Kalispell 1° x 2° quadrangle, Montana, and Alberta and British Columbia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2267, scale 1:250,000.
Hartlaub, R.P., 2009, Sediment-hosted stratabound copper-silver-cobalt potential of the Creston Formation, Purcell Supergroup, southeastern British Columbia (parts of NTS 082G/03, /04, /05, /06, /12), *in* Geoscience BC Summary of Activities 2008: Geoscience BC, Report 2009-1, p. 123–132.
Hayes, T.S., 1983, Geologic studies on the genesis of the Spar Lake strata-bound copper-silver deposit, Lincoln County, Montana: Stanford University Ph.D. dissertation, 340 p.
Hayes, T.S., and M.T. Einaudi, 1986, Genesis of the Spar Lake strata-bound copper-silver deposit, Montana: Part I, Controls inherited from sedimentation and preore diagenesis: Economic Geology, v. 81, p. 1899-1931.
Höy, Trygve, D. Anderson, R.J.W. Turner, and C.H.B. Leitch, 2000, Tectonic, magmatic and metallogenic history of the early synrift phase of the Purcell basin, southeastern British Columbia, *in* J.W. Lydon, Trygve Höy, J.F. Slack, and M.E. Knapp, eds., The Geological Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 33-60.
Huebschman, R.P., 1973, Correlation of fine carbonaceous bands across a Precambrian stagnant basin: Journal of Sedimentary Petrology, v. 43, p. 688-699.
Lane, E.W., 1947, Report of the subcommittee on sediment terminology: Transactions of the American Geophysical Union, v. 28, no. 6, p. 936-938.
Lemoine, S.R., and Don Winston, 1986, Correlation of the Snowslip and Shepard formations of the Cabinet Mountains with upper Wallace rocks of the Coeur d'Alene Mountains, western Montana, *in* S.M. Roberts, ed., Belt Supergroup: A Guide to Proterozoic Rocks of Western Montana and Adjacent Areas: Montana Bureau of Mines and Geology Special Publication 94, p. 161-168.
Lewis, R.S., R.F. Burmester, M.D. McFadden, P.D. Derkey, and J.R. Oblad, 1999, Digital geologic map of the Wallace 1:100,000 quadrangle, Idaho: U.S. Geological Survey Open-File Report 99-390, scale 1:100,000.
Lewis, R.S, R.F. Burmester, J.D. Kauffman, and T.P. Frost, 2000, Geologic map of the St. Maries 30 x 60 minute quadrangle, Idaho: Idaho Geological Survey Geologic Map 28, scale 1:100,000.
Lewis, R.S., R.F. Burmester, R.M. Breckenridge, M.D. McFadden, and J.D. Kauffman, 2002, Geologic map of the Coeur d'Alene 30 x 60 minute quadrangle, Idaho: Idaho Geological Survey Geologic Map 33, scale 1:100,000.
McKee, E.D., and G.W. Weir, 1963, Terminology for stratification and cross-stratification in sedimentary rocks: Geological Society of America Bulletin, v. 64, p. 381-390.
Miller, D.A., Jr., 1973, Geology of the Leonia Knob area, Boundary County, Idaho: University of Idaho M.S. thesis, 103 p.
Miller, F.K., and R.F. Burmester, 2004, Geologic map of the Bonners Ferry 30' x 60' quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-2426, scale 1:100,000.
Poage, M.A., D.W. Hyndman, and J.W. Sears, 2000, Petrology, geochemistry, and diabase-granophyre relations of a thick basaltic sill emplaced into wet sediments, western Montana: Canadian Journal of Earth Sciences, v. 37, no. 8, p. 1109–1119.
Ross, G.M., and Villeneuve, M., 2003, Provenance of the Mesoproterozoic (1.45 Ga) Belt basin (western North America): another piece in the pre-Rodinia paleogeographic puzzle: Geological Society of America Bulletin, v. 115, p. 1191-1217.
Sears, J.W., K.R. Chamberlain, and S.N. Buckley, 1998, Structural and U-Pb geochronological evidence for 1.47 Ga rifting in the Belt basin, western Montana: Canadian Journal of Earth Sciences, v. 35, p. 467-475.
Streckeisen, A.L., 1976, To each plutonic rock its proper name: Earth-Science Reviews, v. 12, p. 1-33.
Weisel, C.J., 2005, Soil survey of Boundary County, Idaho: United States Department of Agriculture, Natural Resources Soil Conservation Service in cooperation with United States Department of the Interior, Bureau of Land Management, University of Idaho College of Agriculture, and Idaho Soil Conservation Commission, Idaho Agricultural Experiment Station, Part I, 144 p., Part II, 452 p.
Winston, Don, 1986, Stratigraphic correlation and nomenclature of the Mesoproterozoic Belt Supergroup, Montana, Idaho and Washington, *in* S.M. Roberts, ed., Belt Supergroup: A Guide to Proterozoic Rocks of Western Montana and Adjacent Areas: Montana Bureau of Mines and Geology Special Publication 94, p. 69-84.
Winston, Don, 2007, Revised stratigraphy and depositional history of the Helena and Wallace formations, mid-Proterozoic Piegan Group, Belt Supergroup, Montana and Idaho, U.S.A., *in* P.K. Link, and R.S. Lewis, eds., Proterozoic Geology of Western North America and Siberia: SEPM Special Publication 86, p. 65-100.

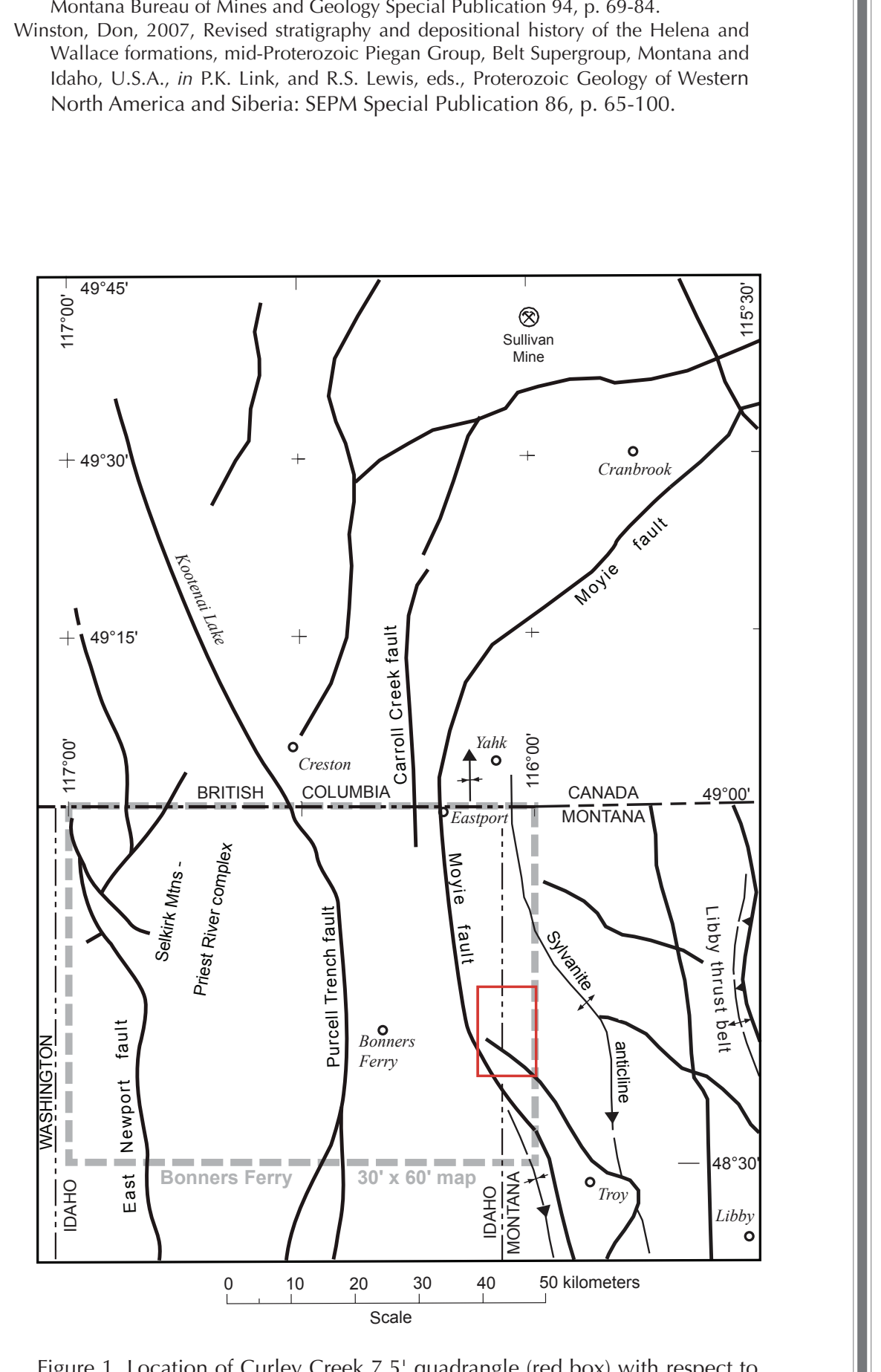


Figure 1. Location of Curley Creek 7.5' quadrangle (red box) with respect to major structural and physiographic features.

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