Geologic Map of the Moyie Springs Quadrangle, Boundary County, Idaho

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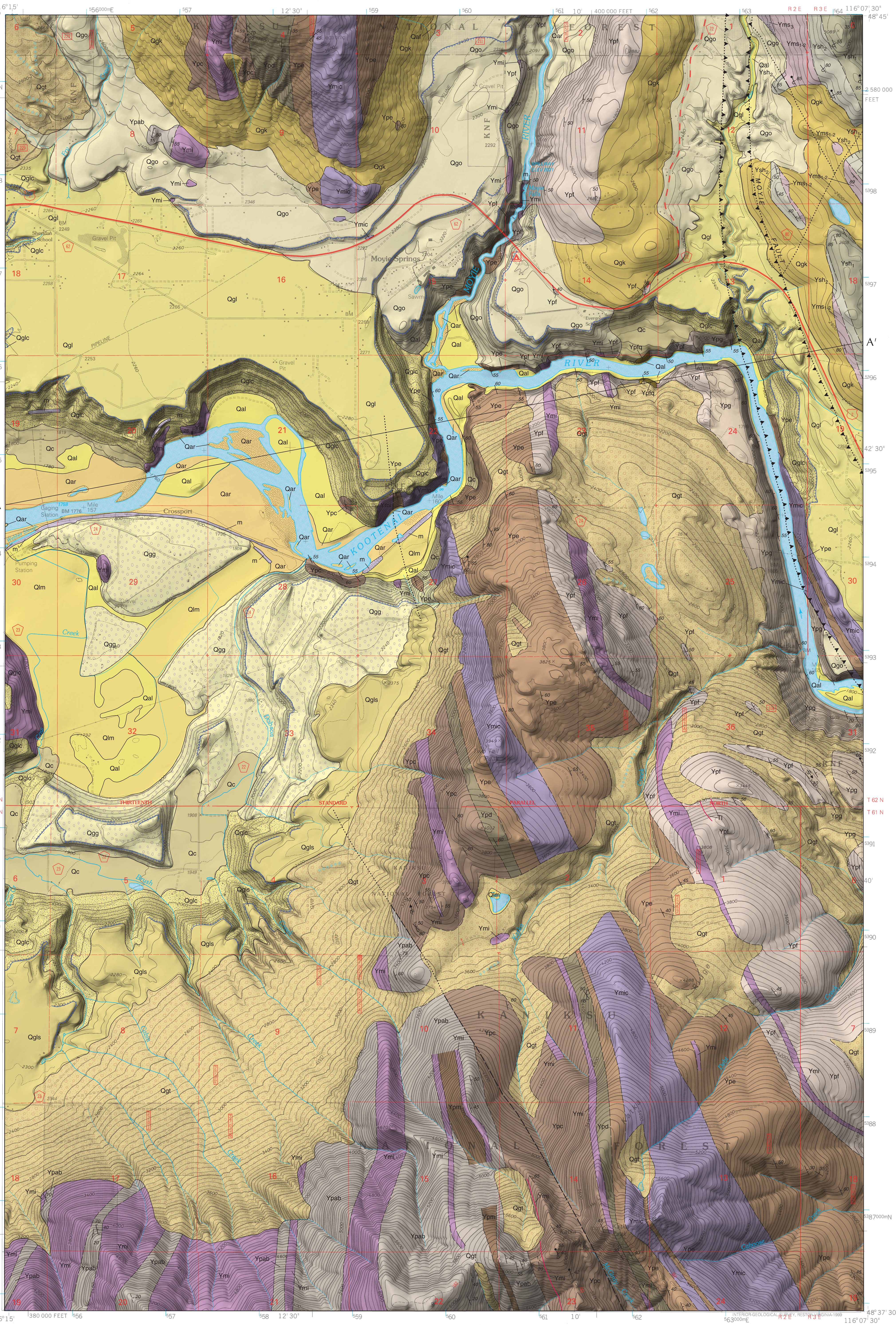
2010



Base digitally scanned from 24,0000-scale USGS film separates, 1996.

Shaded elevation from 10 m DEM.

Topography by photogrammetric methods from aerial photographs taken 1963. Planimetry derived from imagery taken 1992. Public Land Survey System and survey control current as of 1996.

Projection: Idaho coordinate system, west zone (Transverse Mercator). 1927 North American Datum.

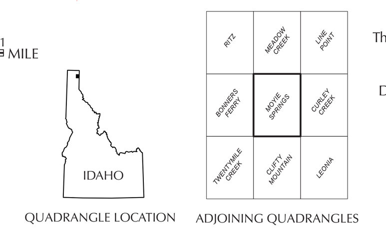
10,000-foot grid ticks based on Idaho coordinate system, central zone.

1000-meter Universal Transverse Mercator grid ticks, zone 11.

UTM Grid and 1996 Magnetic North Declination at Center of Map

SCALE 1:24,000

Contour interval 40 feet
Supplementary contour interval 20 feet



QUADRANGLE LOCATION   ADJOINING QUADRANGLES

Field work conducted 2009.

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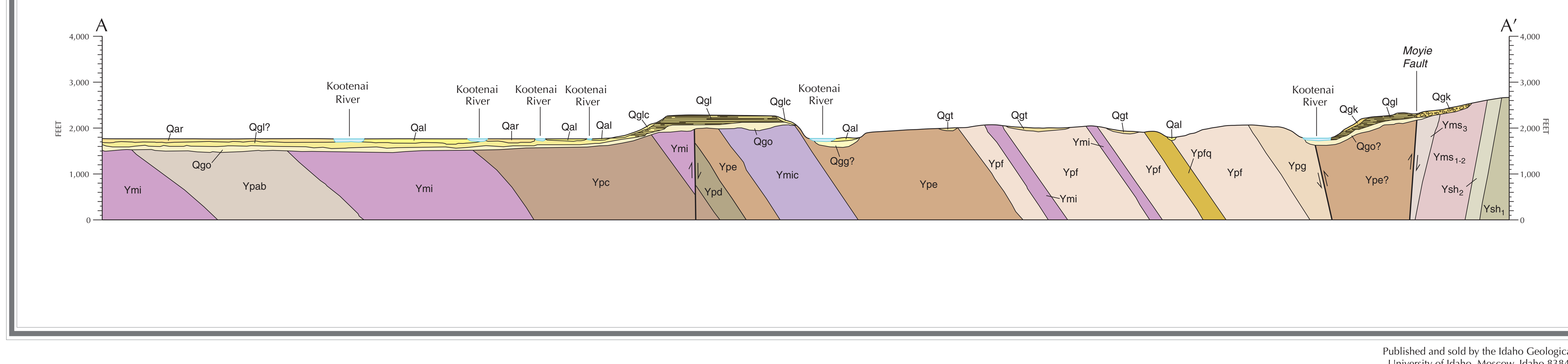
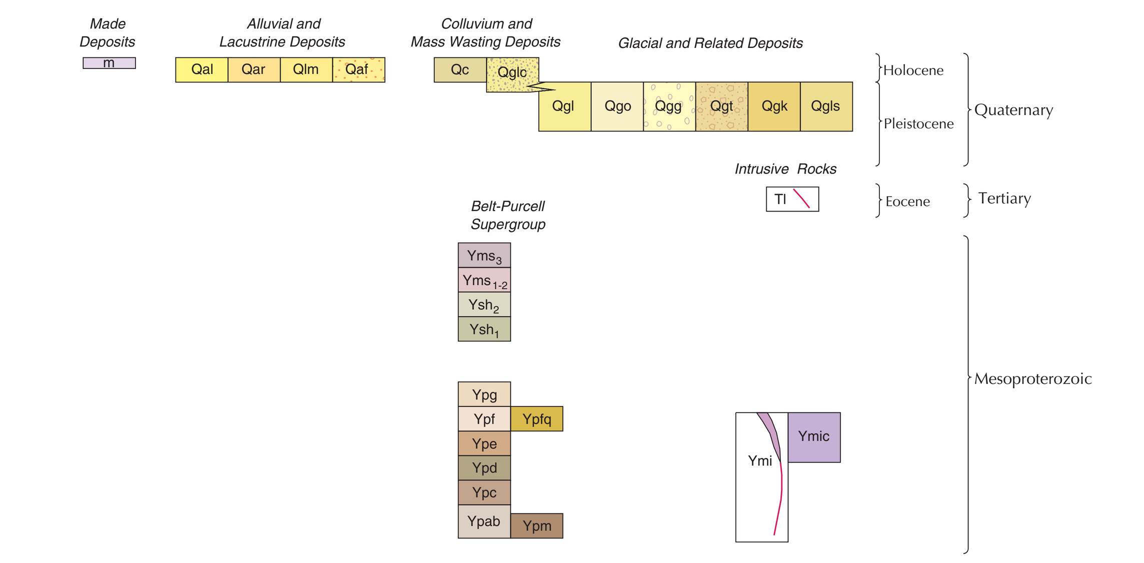
Digital cartography by Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.

Map version 10-14-2010.

PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org.



CORRELATION OF MAP UNITS



INTRODUCTION

Quaternary deposits on this 1:24,000-scale quadrangle were mapped in 1992 and 2008-2009 by R.M. Breckenridge. Bedrock was mapped in 2009 by M.D. McFaddan, R.F. Burmester and R.S. Lewis to modify previous mapping (Burmester, 1986) for consistency with unit definitions and contact placements used in more current mapping to the south.

The most abundant rocks in the Moyie Springs quadrangle are low metamorphic grade metasedimentary rocks of the Belt-Purcell Supergroup, Precambrian in age. The oldest rocks underlie the western part of the map, have tops to the east, and host mafic and differentiated sills. Most of the youngest strata, on the west flank of the Sylvanite anticline east of the Moyie fault (Fig. 1), have tops to the west. Sediments in the lowlands and some at higher elevations date from Pleistocene glaciation and damming of the Kootenai River.

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 both igneous and metamorphic 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). Thicknesses and distances are given in abbreviation of metric units (e.g., dm=decimeter); some linear dimensions in parenthesis are in English units. Multiple lithologies within a rock unit description are listed in order of decreasing abundance. Quaternary units are after Chugg and Fosberg (1980) and Weisel (2005).

MAN-MADE DEPOSITS

m — **made land (historical)**—Highway fills, railroad rights of way, levees of the Kootenai River and the adjacent alluvial flood plain. Numerous small fills are unmapped.

ALLUVIAL AND LACUSTRINE DEPOSITS

Qar — **Active river wash (Holocene)**—Silt, clay, and sand deposits in the active channel and flood plain confined by levees 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 and Moyie rivers and tributaries. Moderately sorted to well-sorted silt, sand, and local pebble and cobble gravels. Mostly reworked glacial deposits in the river valley and post glacial 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 to more than 10 m (6 to >30 ft).

Qaf — **Alluvial fan deposits (Holocene)**—Mixed pebble to cobble gravel deposited as fans at the mouths of local drainages. Mostly subangular to angular clasts derived locally from colluvium and glacial deposits on steep slopes. Thickness is several to more than 5 m (6 to >15 ft).

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

COLLUVIAL AND MASS WASTING DEPOSTS

Qc — **Colluvial deposits (Holocene)**—Silt, sand, and gravel colluvium. Forms debris fans and colluvial aprons along steeper escarpments and gullies of terraces and benches. Includes small unmappable mass movements. This unit mostly in escarpments of *Qglc* where mappable. Varied thickness as much as several meters (15 ft).

Qglc — **Glaciolacustrine deposits (Pleistocene to Holocene)**—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).

GLACIAL AND FLOOD-RELATED DEPOSITS

Qgl — **Glaciolacustrine deposits (Pleistocene to Holocene)**—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 and scattered dropstones. Contorted bedding and loading structures are common. This unit forms several prominent terrace levels from an elevation about 2,200 to 2,300 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 (Pleistocene)**—Silty and sandy gravels. Moderately sorted and rounded pebbles and cobbles. Outwash deposits in this quadrangle are from glaciation of the Moyie River valley that were graded to Glacial Lake Kootenai. Forms a series of terraces at the mouth of the Moyie River. The presence of Glacier Peak tephra (11,200 B.P.) just downstream near Bonner Ferry gives a minimum date for retreat of the ice lobe from the Purcell trench (Richmond, 1986). Soils are sandy loams and loamy sands of the Selle-Elmira Association. Thickness as much as 20 m (60 ft).

Qgg — **Glacial gravel deposits (Pleistocene)**—Coarse cobble and boulder gravel deposits downstream from the junction of the Moyie and Kootenai rivers as they exit from the mountains. Forms a large gravel delta interbedded with glaciolacustrine deposits of Glacial Lake Kootenai. Soils of the Bonner series. Thickness 5-30 m (15-100 ft).

Qgt — **Till deposits (Pleistocene)**—Dense silt, pebble, and cobble till with local boulders deposited by the Purcell Trench lobe of the Cordilleran Ice sheet. Poorly stratified compact basal till includes ground moraine and some interbedded proglacial deposits. Deposit includes kame terraces and some outwash. Soils include silt loams and gravelly silt loams of the Pend Oreille-rock outcrop and the Stien-Pend Oreille associations. Thickness from 1-50 m (3-150 ft) in subsurface.

Qgls — **Glaciolacustrine and ice stagnation deposits (Pleistocene)**—Fine silt and sand with interbedded bar and channel sand and gravel deposits. Thin laminae to thickly bedded sands with some cross bedding. Dunes (giant current ripples?) and closed depressions (kettles?) are the dominant surface features. Soils are very deep fine sandy loams and loamy sands of the Selle-Elmira association. Thickness 2-20 m (6 to 60 ft).

Qgk — **Kame deposits (Pleistocene)**—Poorly stratified and compact silty to sandy boulder lodgement till; locally includes ground moraine and some interbedded proglacial and ice contact and outwash deposits. This unit probably underlies *Qgl* and records the latest recession of 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

Tl — **Lamprophyre dikes (Eocene)**—Biotite lamprophyre dikes with 1-2 mm biotite phenocrysts in a fine-grained groundmass; grain size varies between and within dikes. Known only in center east half of map area. Age presumed similar to a lamprophyre dike that cuts the Sandpoint conglomerate in the Elmira quadrangle (Lewis and others, 2007) to the south, which has an $^{40}Ar/^{39}Ar$ age of 47.15 ± 0.24 Ma on biotite (Doughty and Price, 2000).

Ymi — **Mafic intrusive rocks, undivided (Mesoproterozoic)**—Fine- to medium-grained, rarer coarse-grained hornblende gabbro. Variants range from high color index (CI) hornblendite to low CI differentiates that are most commonly at or near sill tops as medium-grained quartz diorite or biotite granophyre, but also occur separately. Plagioclase rarely as cm-long laths, quartz as 5 mm blue grains or in cm-diameter granophyre concentrations. Variations are common between intrusions and within single bodies both along and across strike. All within the map area are Moyie sills described by Bishop (1976); they are likely from tholeiitic magma or differentiates intruded into the lower and middle parts of the Prichard Formation (Höy, 1989). Intrusions are 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). Sills lower and higher in the section are similar in chemistry (Anderson and Goodfellow, 2000), but they seem to have intruded in at least two separate events. Early intrusions were at shallow levels closely following or were invasive during sedimentation of the Lower Aldridge equivalent *Ypab* (Höy and others, 2000; Gorton and others, 2000; Cressman, 1989; Sears and others, 1998, Poage and others, 2000). Generation of *Ypm* was probably synchronous with shallow intrusive events. Higher intrusions sport chilled margins and contact aureoles, evidence that they invaded consolidated rock at a later time. Age of sills in *Ypab* is probably close to U-Pb dates on zircons from near Kimberley, British Columbia about 100 km to the north (1.468 Ga; Anderson and Davis, 1995) and from Plains, Montana, about 190 km southeast (1.47 Ga; Sears and others, 1998). The younger age from the differentiated top *Ymic* in *Ype* of 1.433 Ga (Zartman and others, 1982) has been attributed to metamorphism (Anderson and Davis, 1995).

Ymic — **Mafic intrusive rocks, Crossport C sill (Mesoproterozoic)**—Fine- to coarse-grained hornblende gabbro, hornblendite, quartz gabbro to quartz diorite. Finer grained variety typically near top and bottom, but also occurs interlayered with coarser phases parallel to upper and lower conformable contacts within the body. Granophyre blotches to 2 cm common near top of unit across most of the map. Hornblendite locally above that has acicular amphibole 2 cm long in contrast to common stubby form. Where observed, lower contact chilled. Thickness near center of map about 360 m (1,200 ft) (Bishop, 1976).

BELT-PURCELL SUPERGROUP

Missoula Group

Mount Shields Formation (Mesoproterozoic)—Red and green quartzite, siltite and argillite, and minor carbonate. Of 6 members recognized to the south (Burmester and others, 2006) only the bottom three are recognized here, and the bottom two are combined on this map.

Yms_3 — **Mount Shields member 3 (Mesoproterozoic)**—Green and red to maroon siltite and argillite couplets. Argillite, typically as skins on siltite, commonly preserves salt crystal casts as squares to 1 cm, as well as rare hopper crystal casts. Mudcracks, mudchip breccias, and muscovitic partings common. Top faulted; base not exposed but elsewhere gradational from underlying *Yms_2*. Thickness 300 m (1,000 ft) to the east (Cressman and Harrison, 1986).

Yms_{1-2} — **Mount Shields members 1 and 2 (Mesoproterozoic)**—Fine-grained pink to pale green quartzite, siltite, maroon argillite, and tan weathering carbonate varieties. Tabular dm beds of quartzite commonly have rippled tops, grade to mm-scale red argillite skins with muscovite concentrations, mud cracks and chips. Carbonate concentrated in upper part as diffuse, roughly horizontal cm-thick irregular wisps of nonresistant brown carbonate within the quartzite, as flat cryptalgal laminations, and as dm-thick nonresistant oolitic layers. Thin bedding here is more characteristic of *Yms_1*, but carbonate content found only in *Yms_2* to the south (Burmester and others, 2006). Top not exposed but elsewhere gradational into *Yms_3*. Thickness estimated as 200 m (660 ft).

Shepard Formation (Mesoproterozoic)—Occupies same stratigraphic level as the upper two units of the Wallace Formation previously mapped the south (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. 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 interpreted as soft sediment deformation. Siltite and quartzite beds to 5 cm. Upper contact placed at base of lowest purple argillite or quartzite of *Yms_{1-2}*. Thickness about 120 m (400 feet). Previously mapped as upper part of the Shepard Formation (Burmester, 1986) and 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 2-5 cm beds of white quartzite. Nonresistant horizontal limestone pods usually weathered out. Some contorted chip layers and soft sediment deformation, small-scale loads and flames typical. Siltite and quartzite commonly cross laminated or as starved ripples that form lenticular bedding. Upper contact placed at lowest black argillite of *Ysh_2*. Thickness uncertain because of faulting and transposition of bedding where folding intense, but probably less than 500 m (1,500 ft).

Lower Belt

Prichard Formation (Mesoproterozoic)—White to gray siltite, white to gray to black argillite, and white to gray feldspathic quartzite and white quartzite. Siltite typically rusty weathering and planar laminated with black argillite tops, some with white argillite tops. Conspicuous bar code-like patterns formed by alternating dark and light siltite in outcrops persist regionally for more than 100 kilometers (Huebschman, 1973). These "marker beds" were used by Cominco for correlation purposes across large areas (Hamilton and others, 2000). Rusty nature of outcrop weathering results from abundant sulfides, commonly pyrrhotite. Average quartzite has 21 percent feldspar (Cressman, 1985) and is lighter weathering in dm beds. With exception of *Ypt*, unit designations follow subdivision of Cressman (1985) from near Plains, Montana, about 90 km to the southeast. Identification of the upper units down through *Ype* benefited from recently released mapping by Cominco geologists (Michael Zientek, written communication, 2003). Cominco did not map below *Ype* and Cressman (1989) was unable to correlate his quartzite unit with subdivisions of Finch and Baldwin (1984), 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 (Lydon, 2008), or the *Ypb-Ypc* contact (Michael Zientek, written communication, 2003).

Ypg — **Prichard Formation, member g (Mesoproterozoic)**—Gray to white feldspathic quartzite and dark gray argillite. Fine- to very fine-grained quartzite as dm, rare 1-2 m beds. Ripple cross lamination, rippled tops, some thin green argillite tops. Some 5-10 cm ovoid concretions have residual calcite. Interlayered with even parallel siltite and white and black laminated siltite and argillite, both planar and uneven. Top not exposed, but thickness west of Scotchman Peak to the south approximately 530-590 m (1,750-1,950 feet; Burmester and others, 2004).

Ypf — **Prichard Formation, member f (Mesoproterozoic)**—Rusty and yellow-green weathering, even parallel-laminated, light and dark gray to blue-gray siltite and dark gray argillite, and minor, lighter quartzite. Upper part is mostly dark, pyrrhotite-bearing argillite and siltite with marker-bed-like (Huebschman, 1973) color layering common. Tabular beds of very fine- to fine-grained biotitic quartzite more abundant toward base; most are dm scale with tops graded to dark argillite, more rarely rippled; some have carbonate as concretions to dm in diameter and rarely distributed along bedding. Hosts relatively thin and undifferentiated sills D and E of Bishop (1976). Thickness possibly 1,300 m (4,300 ft) including sills. Upper contact is gradational, placed above the highest occurrence of thick argillite and below a concentration of thick and amalgamated siltite beds with current features.

Ypfq — **Prichard Formation, member f quartzite (Mesoproterozoic)**—Light gray to white-weathering fine-grained feldspathic quartzite. Mapped only where well enough exposed to show dominance of dm- and m-thick quartzite beds. Those range from tabular to broad channel shaped.

Ype — **Prichard Formation, member e (Mesoproterozoic)**—Light gray to white weathering siltite and quartzite and darker argillite, some light argillite. Decimeter siltite dominates over feldspathic quartzite. Some beds parallel laminated, but most uneven or undulating, and exhibit features of current traction such as rippled tops, ripple cross lamination and trough cross bedding. Small-scale soft-sediment deformation features common; cm-scale load casts and ball and pillow structures locally abundant, matrix-supported sedimentary breccia rare. Quartzite beds to 2 m thick have channel or load bases. Some that are coarser grained and less feldspathic than typical of the Prichard have rounded medium quartz grains, especially at bed bases. These, perhaps in thinning and fining upward sequences, have discontinuous carbonate horizons and concretions more rarely than overlying unit. Upper contact placed above highest zone of quartzite with abundant current features and below thick section of uniformly parallel laminated rusty weathering siltite. Quartzite-rich sections commonly form clear ribs and talus slopes. Thickness approximately 1,400 m (4,600 ft) including *Ymic*.

Ypd — **Prichard Formation, member d (Mesoproterozoic)**—Laminated, generally tabular light gray siltite and dark gray argillite. Most laminations on the order of cm and even. Less abundant are intervals of mm even parallel laminated to microlaminated, rusty weathering, dark to light gray siltite and dark gray to light gray-green argillite couplets. Interspersed are intervals a few m in thickness of white, very fine- to fine-grained quartzite in rarely amalgamated beds, or rusty weathering dm white 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*. Thickness 300-500 m (1,000-1,600 ft); range probably due to poor exposure of contacts.

Ypc — **Prichard Formation, member c (Mesoproterozoic)**—Light-weathering quartzite, darker siltite, and rusty weathering argillite. Mostly uneven or undulating couplets of light weathering very fine-grained quartzite or siltite grading to dark, rusty weathering argillite. Some light argillite tops. Fine-grained to rare medium-grained, poorly sorted feldspathic quartzite beds typically 30-50 cm but as much as 3 m thick scattered throughout the unit. Some beds have ripples and cross lamination, coarser grains at bases and gradation to siltite at the top. Others have internal laminations disrupted or appear structureless, perhaps because of complete disruption. Circular brown spots to 6 cm diameter with alteration "halos" probably formed from concentrations of (magnesium) carbonate. Toward south, smaller concretions metamorphosed to calc-silicates. Hosts one or two thin, undifferentiated sills. Top placed above set of quartzite beds and below interval of more evenly laminated siltite and argillite. Thickness estimated at 700 m (2,300 ft) including sills.

Ypm — **Prichard Formation, massive unit (Mesoproterozoic)**—Structureless, poorly sorted quartzite and siltite to quartz-rich fine-grained biotite granodiorite. Commonly has granofels texture with fine biotite and muscovite common. Granophyre and myrmekite intergrowths suggest an igneous or magmatic fluid contribution, but similar rock to the south has too much quartz to be entirely igneous (Redfield, 1986). Found to the south of the area as irregularly shaped bodies within *Ypab*, but seems to be stratiform in this area, although not continuous laterally. Laminated strata at similar stratigraphic level show soft sediment deformation. Commonly floored by, less commonly capped by mafic sills. Locally contains 5 percent clasts of Prichard lithologies, commonly laminated siltite and argillite, a few cm thick. Some clasts have apparent reaction rims and (or) appear deformed. Weathers more rusty than quartzite of *Ype* or *Ypc*. Generally hardest rock of the Prichard Formation, forming rounded exposures, float, and large blocky talus. May have formed from increased pore fluid pressure due to heating by the sills (Anderson and Höy, 2000).

Ypab — **Prichard Formation, members a and b (Mesoproterozoic)**—Even parallel laminated, rusty weathering, dark gray siltite and argillite couplets, siltite, and lighter quartzite. Couplets typically not graded and less than one cm thick; argillite tops locally light weathering. Siltite layers cm and dm scale, typically dark gray, some weathering light gray. Light gray to white weathering quartzite as isolated dm-scale beds and bases of graded couples, and dm- to rare m-scale beds amalgamated as much as several m thick. Soft sediment deformation, including folds and intraformational breccias at scales from dm to tens of m, abundant, perhaps characteristic of this unit or at least its upper part near *Ypm*. Hosts Moyie sills that range from tabular to irregular, some with differentiated, quartz- or granophyre-rich tops. Top placed above horizon of *Ypm* at base of section of relatively abundant m-thick quartzite that contains medium quartz grains and preserves ripples and cross lamination. Base is not exposed.

STRUCTURE

The major structure in the map area, although not exposed, is the Moyie fault. It is characterized regionally as an east-vergent thrust, and does juxtapose older rocks on the west against younger ones on the east, consistent with this interpretation. However, those rocks 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 area (Miller and Burmester, 2004), an open, northward-plunging syncline east of the fault north of the international border (Brown and others, 1995), and a sliver of east-facing upper Belt strata east of the fault near the northeast corner of this map. Latest motion on the Moyie fault was probably down to the west, as was motion on a fault to its west and parallel to it that repeats part of the Prichard Formation and *Ymic* at the east edge of the map.

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SYMBOLS

Contact: dashed where approximately located.

Normal fault: dashed where approximately located; dotted where concealed.

Thrust fault: teeth on upper plate; dotted where concealed.

Moraine crest or kame ridge.

Strike and dip of bedding.

Strike and dip of bedding known to be upright.

Estimated strike and dip of bedding.

Strike and dip of bedding interpreted to be overturned.

Strike and dip of bedding known to be overturned.

Strike and dip of jointing.

Strike and dip of cleavage.

Bearing and plunge of asymmetrical small fold showing clockwise rotation viewed down plunge.

Bearing and plunge of asymmetrical small fold showing counterclockwise rotation viewed down plunge.

Kettle.

Terrace escarpment.

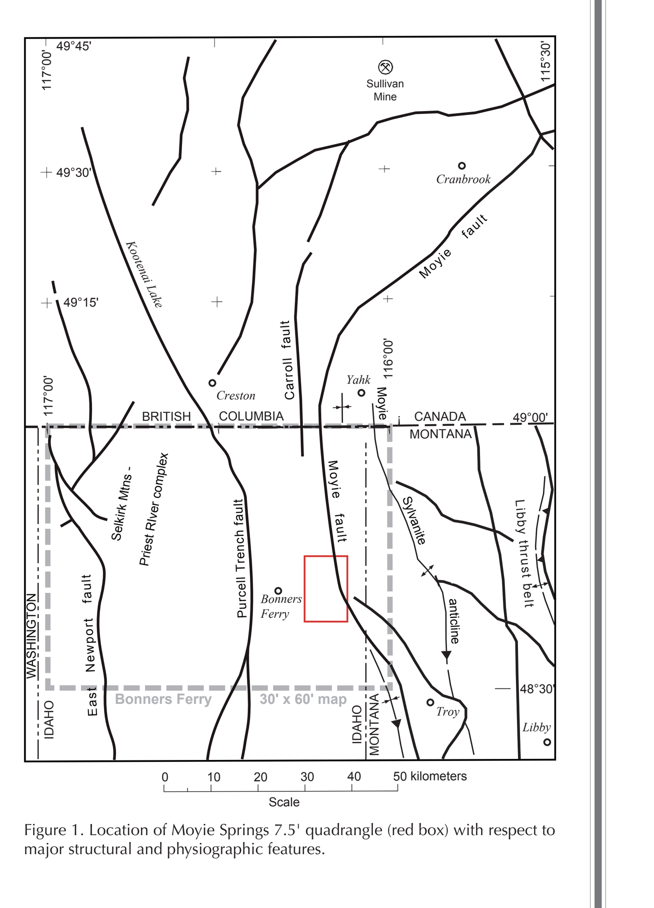

Figure 1. Location of Moyie Springs 7.5' quadrangle (red box) with respect to major structural and physiographic features.

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