Geologic Map of the Line Point Quadrangle, Boundary County, Idaho, and Lincoln County, Montana

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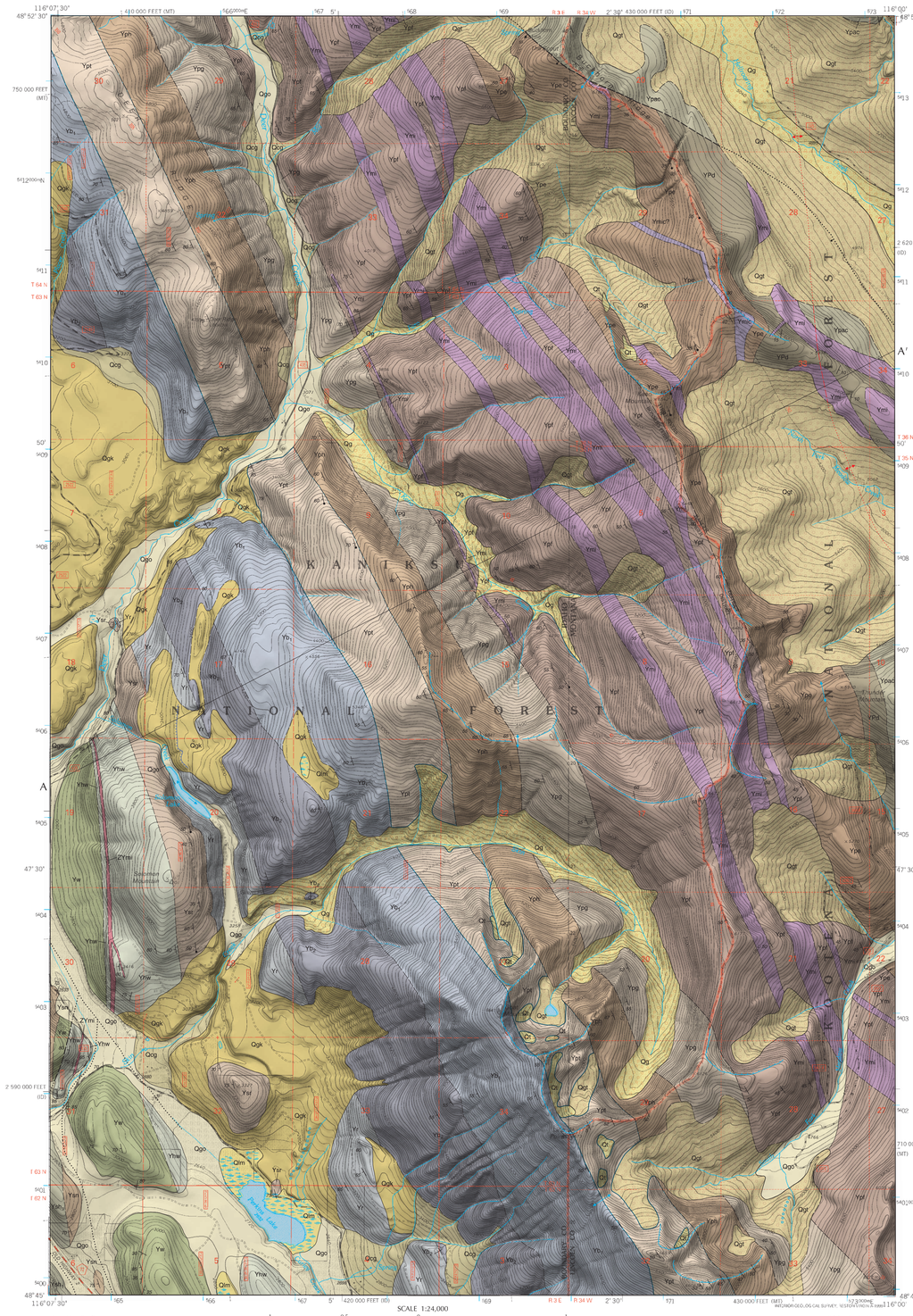
2012



SCALE 1:24,000

0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
0.5 0 1 KILOMETER

Contour interval 40 feet
Supplementary contour interval 20 feet

0° 43' 18°
UTM Grid and 1996 Magnetic North Declination at Center of Map

QUADRANGLE LOCATION

ADJOINING QUADRANGLES

Base Map Credit

Base digitally scanned from 24,000-scale USGS film separates, 1996.

Shaded elevation from 10 m DEM.

Topography compiled 1963. Planimetry derived from aerial photographs taken 1992.

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

10,000-foot grid ticks based on Idaho coordinate system, west zone and Montana coordinate system, north zone.

1000-meter Universal Transverse Mercator grid ticks, zone 16.

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Field work conducted 2009-2011.

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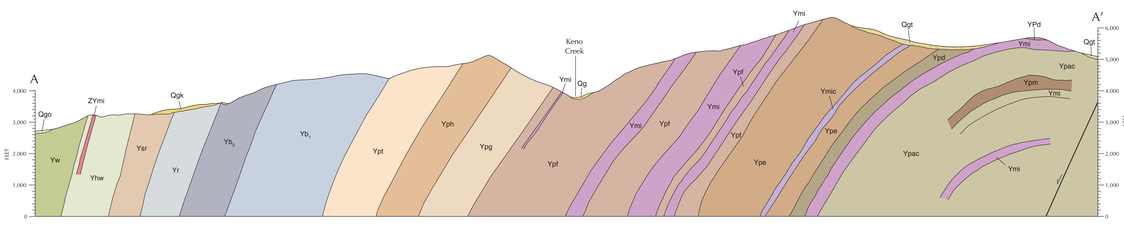
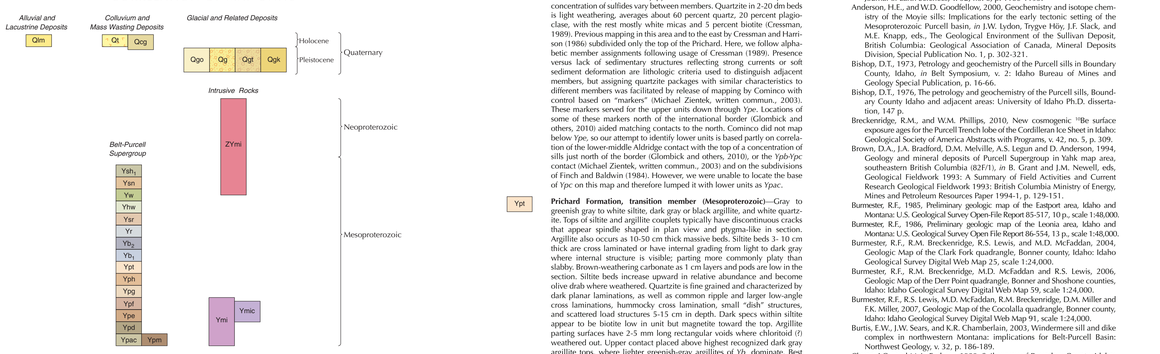
Reviewed by John D. Kauffman, Susan M. Vuke, and Catherine McDonald.

Map version 11-16-2012.

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



CORRELATION OF MAP UNITS



INTRODUCTION

Quaternary deposits on the Line Point quadrangle were mapped in 2010 and 2011 by R.M. Breckenridge. Bedrock was mapped in 2009 and 2011 by R.F. Burmester, M.D. McFaddan, and R.S. Lewis and in 2011 by J.D. Lonn to modify previous mapping (Burmester, 1985) for consistency with unit definitions and contact placements used in more recent mapping.

The oldest and most abundant rocks in the quadrangle are low metamorphic grade metasedimentary rocks of the Mesoproterozoic Belt-Purcell Supergroup. The lowest strata host penecontemporaneous mafic and differentiated sills. All are exposed on the west flank of the Sylvanite anticline east of the Moyie fault (Fig. 1). During Pleistocene glaciations, the Cordilleran Ice Sheet repeatedly advanced southward across the quadrangle from Canada. Cosmogenic ^{10}Be surface exposure ages (mean weighted) constrain the glacial maximum ice limit near the Clark Fork ice dam 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 valleys. After retreat of the continental ice, mountain valley glaciers persisted in the higher cirques of the Purcell Mountains.

SYMBOLS

- Contact: dashed where approximately located.
- Normal fault: ball and bar on downthrown side; dashed where approximately located; dotted where concealed.
- Strike and dip of bedding.
- Strike and dip of bedding; ball indicates bedding known to be upright.
- Strike and dip of overturned bedding.
- Strike and dip of, strike variable.
- Strike and dip of cleavage.
- Ice flow direction.
- Col.
- Terrace escarpment.
- Cirque headwall: ticks on glaciated side.
- Moraine crest or kame ridge.

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 thickness and distances are listed in both meteric and English units. 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

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 tans and colluvial aprons along steep valleys and gullies mostly derived of glacial deposits. Includes small unmappable mass movements. Thickness varies, typically 5 m (15 ft).

GLACIAL DEPOSITS

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 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 along the south margin. 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 deposits. 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 (Neoproterozoic or Mesoproterozoic)**—Fine- to medium-grained diorite or gabbro. Locally contains calcite and possibly actinolite, probably from greenschist facies metamorphism. Occurs as sills of varied thicknesses and continuity. Intrusion into units above Prichard Formation indicate that they cannot be Moyie sills. May be coeval with the Purcell lava (rhyolite about 55 km (35 mi) east-northeast dated 1.443 Ga; Evans and others, 2000), or possibly a sill complex farther east (760 Ma; Burris and others, 2003).

Ymi **Mafic intrusive rocks, undivided (Mesoproterozoic)**—Fine- to medium-grained, rarer coarse-grained hornblende gabbro and quartz diorite. Variants have laths of plagioclase, or quartz as large blue grains or in granophyre. Grain size, quartz, and mafic mineral content vary between intrusions and commonly within single bodies, both along and across strike. Occur as Moyie sills in *Ypf* and lower units, locally 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). Age of these sills is probably close to U-Pb dates on zircons from near Kimberley, British Columbia, about 100 km (60 mi) north (1.468 Ga; Anderson and Davis, 1995), and from Plains, Montana, about 190 km (120 mi) south-southeast (1.47 Ga; Sears and others, 1998). Higher intrusions sport chilled margins and contact aureoles, evidence that they invaded consolidated rock at a later time. Best observed near Keno Mountain.

Ymic **Mafic intrusive rocks, Crosscort C sill (Mesoproterozoic)**—Fine- to coarse-grained hornblende gabbro to quartz diorite. Correlated with the middle or "C" sill of (Bishop, 1973, 1976) defined in the Moyie Springs quadrangle to the southwest based on occurrence low in *Ype* across Buckhorn Ridge, northeast corner of map. Thickness about 60 m (100 ft).

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 consisting of quartzite, siltite, and argillite. Only the lowest two formations are mapped here.

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 strata (*Ysn*). Subdivision follows Lemoine and Winston (1986) and Burmester (1985), but only the lower unit is exposed in this quadrangle.

Yshy1 **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. Nonresistant horizontal limestone pods usually weathered out. Contorted chip layers, soft sediment deformation, and centimeter-scale loads and flames are typical. Siltite and quartzite are commonly cross-laminated or occur as starved ripples that form lenticular bedding. Top not on map; thickness to the south 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 (Lewis and others, 1999, 2000). Total thickness there about 900 m (3,000 ft). Discontinuous exposure and faulting preclude accurate determination of thickness or subdivision within this map.

Ysn **Snowslip Formation (Mesoproterozoic)**—Dark green siltite and light green argillite graded and nongraded couplets, green siltite and dark gray argillite couplets, purple siltite and argillite couplets, and green to gray siltite. Lower part is dominantly green couplets with a purple zone near its middle. All characteristically have mud and dewatering cracks. Middle part is 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 planar parallel lamination is widespread in middle of unit elsewhere (Burmester, 1986; Burmester and others, 2006; Lewis and others, 1999). Upper part is dominantly green with minor carbonate. Upper contact placed below concentration of carbonate-bearing lenticular couplets or thick white quartzite of *Ysh*$_y$. Parts exposed along Deer Creek Road (FS Road 435) in the southwest corner of the map. Thickness possibly 550 m (1,800 ft).

Piegan Group

The Piegan Group was resurrected by Winston (2007) to provide group-level correlation 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). Since the strata below the Wallace in most of Idaho are appreciably different from those in the Helena's new reference section in Glacier National Park, we distinguish these 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. Siltite and quartzite commonly as bases of pinch-and-swell couplets and couples graded to dark argillite tops. Argillite caps commonly 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. Upper contact not exposed, but elsewhere placed at the top of pinch-and-swell couplets with black argillite caps. Best exposures are near mouth of Solomon Creek and section 6-5 line near south edge of map. Minimum thickness 220 m (700 ft), much less than to the south (790 m, 2,600 ft; Burmester and others, 2004). Zircons from a tuff near the 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. Carbonate-bearing uneven green siltite and argillite laminae and couplets are concentrated near base. 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). Contains 1-2 mm pyrite cubes. Includes zones of carbonate-free laminated to thin-bedded green siltite and lighter green argillite 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 Deer Creek Road near mouth of Solomon Creek. Thickness on the order of 150-240 m (500-800 ft). Unit corresponds to the Helena and Empire formations to the east (Harrison and others, 1992).

Ravalli Group

The swath of Ravalli Group strata across 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 mud cracked. Includes discrete layers of thin mudchips 1-3 cm thick. Green lithologies are more common toward the top. These 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. Upper contact placed above highest cracked and mudchip-bearing purple siltite and argillite. Parts well exposed along FS Road 2549 to Solomon Mountain, along top cliff west of Solomon Lake, and along Deer Creek near west edge of map. Thickness from map pattern about 450 m (1,500 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 or 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. Mud cracks and chips are distributed throughout. Contains visible magnetite octahedra as reported to the east (Harrison and others, 1992). Poor exposure in area attributed to fracturing of brittle quartzite into small cubes during deformation. Upper contact placed above highest thick white quartzite. Top best exposed south of Solomon Lake along FS Road 2404. Thickness about 400 m (1,300 ft).

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

Yby2 **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 mm-thick skins of dark green and some lighter green argillite. Sedimentary features include cross lamination, ball and pillow structures, rare convolute lamination, and rare thin mud chips. 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 present near top. Upper contact placed at base of lowest thick white quartzite. Best exposed on rib north of Skin Creek, southwest part of map. Thickness approximately 550 m (1,800 ft).

Yby1 **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 on FS Road 2540 and spurs northwest of Deer Ridge Lookout. Thickness approximately 550 m (1,800 ft).

Ype **Prichard Formation, member e (Mesoproterozoic)**—Light gray- to white-weathering siltite and quartzite, and darker argillite. Rustier-weathering gray siltite found as 1-5 dm tabular beds. Lighter siltite occurs as graded tops of quartzite beds, less commonly as their inversely graded bases. Most quartzite is light gray, poorly sorted, fine grained and feldspathic in 2 dm to 2 m thick beds, some of which contain carbonate concretions or biotite-rich zones 1-10 cm across. Exceptions are coarser grained and less feldspathic and have rounded medium quartz grains dispersed or concentrated at bed bases. Bases commonly convolute or loaded into subjacent laminated intervals. Some beds are parallel laminated with laminated siltite and argillite caps, but more exhibit features of current traction such as trough cross bedding, ripple cross lamination, rip-up clasts, and rippled tops. Clasts, typically near tops of beds, are composed of white argillite, quartzite, and siltite, and are 2-20 cm long, variously rounded, distorted or stretched. Soft-sediment deformation features common; ball-and-pillow structures locally abundant. Quartzite-rich sections include amalgamated beds and commonly form clear ribs and talus slopes. Very dark argillite found as rare layers 2-10 cm thick. Upper contact placed above highest zone of quartzite with abundant current features and below thick section of uniformly parallel-laminated rusty-weathering siltite. Best exposed on Keno Mountain and the ridge to the south. Thickness approximately 1,200 m (3,600 ft).

Ypd **Prichard Formation, member d (Mesoproterozoic)**—Dark to light gray siltite and darker gray argillite. Lamination is typically even and parallel in siltite and argillite couplets and in microlaminae. Rusty weathering is common. Less common are intervals a few meters in thickness of white, very fine- to fine-grained quartzite in rarely amalgamated beds, or rusty-weathering 1-5 dm white siltite. A zone of contorted beds near end of thin sill, above a larger one, is atypical. Exposure generally poor and discontinuous, with quartzite commonly over-represented in float. Upper contact placed at lowest occurrence of current-laminated siltite and quartzite of *Ype*. Best exposure in map is east of ridge northeast of Keno Mountain. Thickness 200-500 m (600-1,600 ft); range uncertainty due to poor exposure of contacts.

Ypac **Prichard Formation, members a, b, and c (Mesoproterozoic)**—Light weathering quartzite, darker siltite, and rusty-weathering unevenly laminated, dark gray siltite and argillite couplets. Fine-grained to rarely medium-grained quartzite, similar to that of *Ype* but in thinner packages, is characteristic of the upper part. Some beds have ripples and cross lamination; other beds 1-3 m thick, appear structureless. Circular brown spots 3-6 cm in diameter with alteration "halos" probably formed from concentrations of manganiferous carbonate. Top placed above set of quartzite beds and below interval of more evenly laminated, rustier weathering siltite and argillite. Lower part not exposed in map, but a stratigraphically lower massive unit is exposed in the Canuck Peak quadrangle to the north and the Mount Baldy quadrangle to the east (Cressman and Harrison, 1986). Gravity modeling (Kleinkopf, 1977) suggests that there is a minimum of 3,000 m (10,000 ft) of sedimentary strata between the massive unit and basement. Best exposed northeast of Buckhorn Ridge, north edge of map.

Ypm **Prichard Formation, massive unit (Mesoproterozoic)**—Structureless, poorly sorted quartzite and siltite shown only in cross section. Location based on west-dipping exposures mapped by Cressman and Harrison (1986) immediately east of quadrangle.

STRUCTURE

The major structure in the area is the Sylvanite anticline. Strata over most of the map are on the nearly homoclinal west limb, but the hinge line crosses the northeast corner. Gravity modeling suggests the anticline is cored by a fault slice of crystalline basement (Kleinkopf, 1977). The southwest corner of the map is complicated by faults that repeat and attenuate the highest strata.

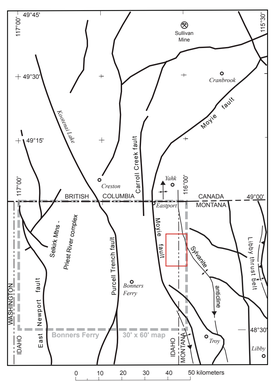


Figure 1. Location of Line Point 7.5' quadrangle (red box) with respect to major structural and physiographic features.

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.

Bishop, D.T., 1973, Petrology and geochemistry of the Purcell sills in Boundary County, Idaho, *in* Belt Symposium, v. 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 ^{10}Be 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., 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 Geological Fieldwork 1993: British Columbia Ministry of Energy, Mines and Petroleum Resources Paper 1994-1, p. 129-151.

Burmester, R.F., 1985, Preliminary geologic map of the Eastport area, Idaho and Montana: U.S. Geological Survey Open-File Report 85-517, 10 p., scale 1:48,000.

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. McFaddan, 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. McFaddan 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. McFaddan, R.M. Breckenridge, D.M. Miller and F.K. Miller, 2007, Geologic Map of the Cocolalla quadrangle, Bonner county, Idaho: Idaho Geological Survey Digital Web Map 91, scale 1:24,000.

Burtis, E.W., J.W. Sears, and K.R. Chamberlain, 2003, Windermere sill and dike complex in northwestern Montana: implications for Belt-Purcell Basin: Northwest Geology, v. 32, p. 186-189.

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 1533, 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 Montana: 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 Publication 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 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.

Kleinkopf, M.D., 1977, Geophysical interpretations of the Libby Thrust Belt, northwestern Montana: U.S. Geological Survey Professional Paper 1546, 22 p., 2 plates.

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. McFaddan, 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, R.M. Breckenridge, M.D. McFaddan, 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.

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.

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 1, 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.

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