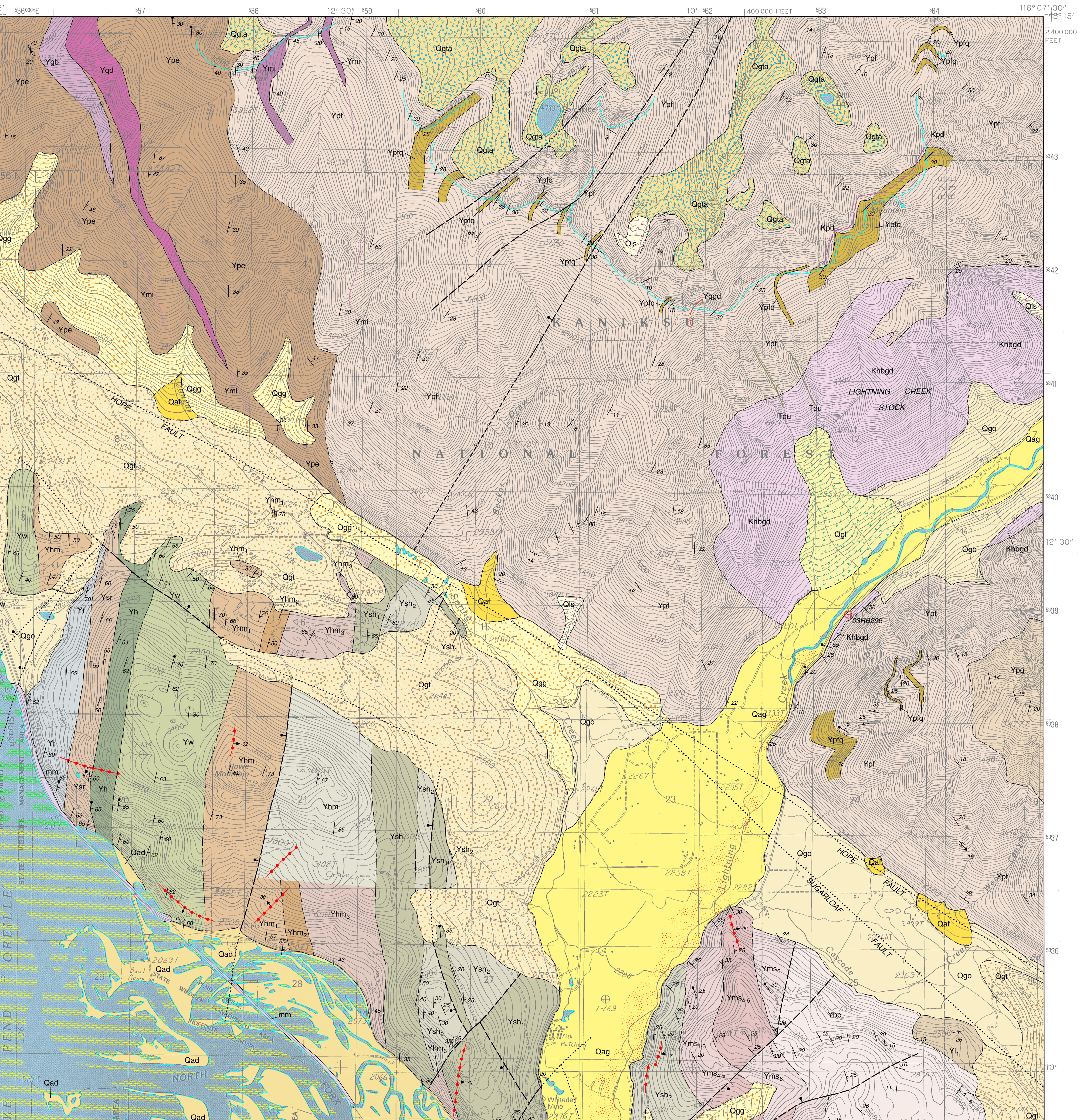
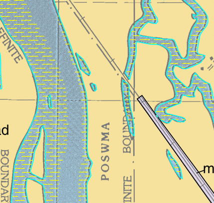
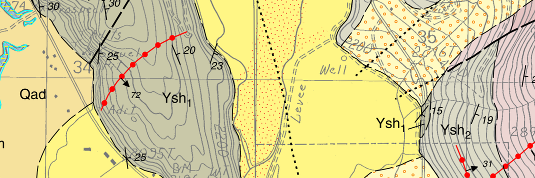
Geologic Map of the Clark Fork Quadrangle, Bonner County, Idaho

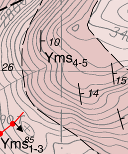
Compiled and Mapped by
Russell F. Burmester, Roy M. Breckenridge, Reed S. Lewis, and Mark D. McFaddan
2004



Base map scanned from USGS film-positive base, 1989.
Topography by photogrammetric methods from aerial photographs taken 1986. Field checked 1987. Map edited 1989.
Transverse Mercator. 1927 North American Datum.
10,000-foot grid ticks based on Idaho coordinate system, west zone.
Grid: 1000 meter Universal Transverse Mercator, zone 11.
1000-meter Universal Transverse Mercator grid ticks, zone 11.

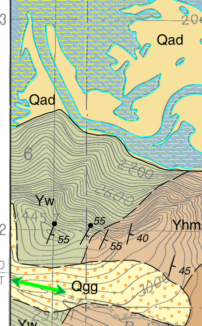




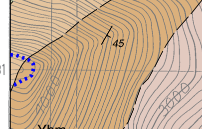


Field work conducted 1990-2003.
This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program.
Digital cartography by Loudon R. Stanford at the Idaho Geological Survey's Digital Mapping Lab.
Map version 7-12-2004.

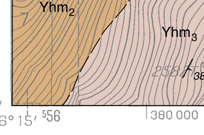
SYMBOLS



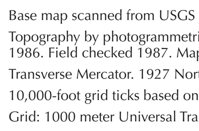
Contact: Line showing the boundary between one map unit and another; dashed where approximate. The location accuracy of contact is 80 feet or more on the ground.
Strike and dip of bedding.
Strike and dip of fracture cleavage.
Strike and dip of bedding, ball indicates bedding known to be upright.
Bearing and plunge of asymmetrical small fold showing counterclockwise rotation viewed down plunge.
Fault: High-angle fault; ball and bar indicates downthrown side of a normal fault; dashed where approximately located; dotted where concealed.
Quartz vein: Arrow indicates dip.
Sample location.



Ice or flood gap.
Maximum elevation of Glacial Lake Missoula approximately 4260'.



Dry falls and cataracts of Missoula Floods.



Headwalls of alpine cirques.
Ice flow direction indicators.

Disclaimer: This Digital Web Map is an informal report and may be revised and formally published at a later time. Its content and format may not conform to agency standards.

INTRODUCTION

Geology depicted on this 1:24,000-scale Clark Fork 7 ½' quadrangle is based partly on previous 15' mapping by Harrison and Jobin (1963). The area was remapped at a larger scale primarily to show glacial and flood-related deposits that record Quaternary events. In addition, we remapped the bedrock during five weeks of field work in 2003 to apply some different unit definitions and contact placements for consistency with more current mapping. We also made additional subdivisions within the Prichard Formation based on recently released mapping to the north by Cominco geologists (Michael Zientek, written communication, 2003). See Harrison and Jobin (1963) for the history of naming units in the area; departures from their naming scheme are explained below within descriptions of affected units. Overall, the bedrock interpretations of the map differ little from those of Harrison and Jobin (1963); visual differences are attributable to slight changes in placement of contacts and the more detailed topography of the 1:24,000 base map. Small substantive differences result from assignment of some rocks, primarily black argillite, to different units, which requires different structural relations.

The oldest and most abundant rocks in the Clark Fork quadrangle are low metamorphic grade metasedimentary rocks of the Belt-Purcell Supergroup, Precambrian in age, some of which host penecontemporaneous mafic and differentiated sills. Plutonic rocks of Cretaceous age also are present as intrusions within the Belt Supergroup. Sediments in the Clark Fork drainage, along valley walls, and below the high mountain cirques date from Pleistocene glaciation and catastrophic floods from glacial Lake Missoula. Glacial Lake Missoula reached a maximum elevation of 1300 m (4260 feet) in the Clark Fork valley behind the Clark Fork ice dam. The actual position of the ice front at any one time was between Pend Oreille Lake and Thompson Falls, Montana.

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 modified Wentworth scale (Lane and others, 1947).

MAN-MADE DEPOSITS

mm **Made land (Historical)**—Mixed deposits of man-made fill. Mostly coarse boulder ballast, cobbles, and boulders. Made land includes highway and railroad beds and constructed levees.

ALLUVIAL AND LACUSTRINE DEPOSITS

Qal **Alluvium (Holocene)**—Mixed fine- to coarse-grained sand and gravel deposits in modern stream valleys tributary to the Clark Fork. Some coarse gravel clasts are reworked from older Holocene and Pleistocene alluvial and glacial units. Soils are silt to sandy loams of the Capehorn and Colburn series. Variable thickness usually 1-3 m (3-10 feet).

Qlm **Lacustrine mud (Holocene)**—Soft sandy and clayey silts deposited in Lake Pend Oreille and Denton Slough. Prior to 1948 the mean water level of the lake was 2048 feet. The current mean level is 2062 feet and is controlled by inflow of the Clark Fork River at Cabinet Gorge Dam and by outflow of the lake in the Pend Oreille River at Albeni Falls Dam. Thickness varies. Soils of the Colburn and Wrencoe series. Dash pattern indicates the location of submerged *Qlm*.

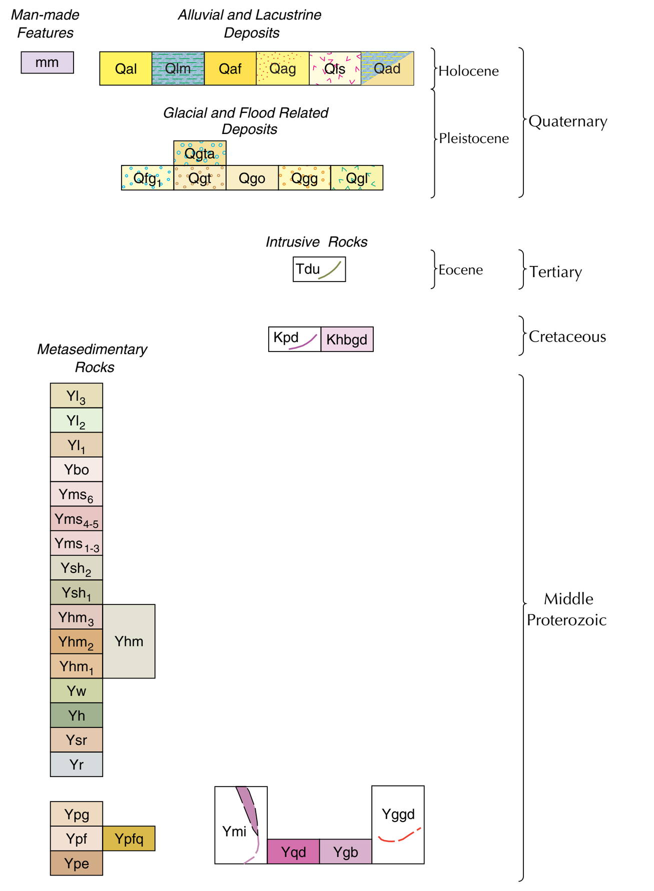
Qaf **Alluvial fan deposits (Holocene)**–Mixed pebble to cobble gravel deposited as fans at the mouth of local drainages. Mostly subangular to angular platy clasts derived locally from the Belt-Purcell Supergroup. Soils mainly of the Colburn, Pend Oreille, and Bonners series (Weisel and others, 1982). Thickness 1-10 m (3-33 feet).

Qag **Alluvial gravel deposits (Holocene)**–Sandy cobble- to large boulder-gravels in modern flood plain of Lightning Creek drainage, usually transported during high discharge spring snowmelt and heavy storm runoff events. Rounded and subrounded clasts derived from intrusive and Belt-Purcell Supergroup rocks. Mostly consists of reworked Pleistocene glacial and flood deposits. Soils of the Capehorn and Colburn series (Weisel and others, 1982). Thickness 5-10 m (16 -33 feet). The active modern riverwash channel varies but is approximately shown by the stipple pattern.

Qls **Landslide deposits (Holocene-Pleistocene)**–Poorly sorted and poorly stratified sandy cobble and boulder gravel mixed with silt and clay. Mass-movements mainly associated with till, outwash, and glaciolacustrine sediments deposited on glaciated bedrock surfaces in the Lightning Creek drainage. Soils of the Bonner and Dufort series (Weisel and others, 1982). Variable thickness as much as 10s of m (100 feet).

Qad **Alluvium and deltaic deposits of the Clark Fork River (Holocene- Pleistocene)**—Interbedded alluvium at the mouth of the Clark Fork River and its delta in Pend Oreille Lake. Consists of soft clayey silt; at depth is locally underlain by late glacial outwash, till, or Missoula Flood deposits. The pattern designates the distribution of the unit prior to construction of Albeni Falls Dam. Thickens quickly into Pend Oreille Lake to many meters. Soils include Colburn and Wrencoe series. Dash pattern indicates the location of submerged *Qad*.

CORRELATION OF MAP UNITS



GLACIAL AND FLOOD-RELATED DEPOSITS

Qgta **Alpine till deposits (Pleistocene)**—Coarse, stony, unsorted sandy cobble to boulder till and protalus deposited by latest Pleistocene and neoglacial glaciers about 1500 m (5000 feet) elevation and above in the Cabinet Range. These valley glaciers postdated the Late Glacial Lake Missoula. Soils (Weisel and others, 1982). Thickness to 15 m (50 feet).

Qgt **Till deposits (Pleistocene)**—Dense clayey pebble and cobble till with local boulders deposited by the Clark Fork tongue of the Purcell Trench Lobe. Compact basal till includes ground moraine and some proglacial deposits formed by calving and meltwater discharge into Glacial Lake Missoula. Soils of the Pend Oreille and Vay-Ardboo series (Weisel and others, 1982). Thickness varies; may exceed 50 m (160 feet).

Qgo **Outwash gravel (Pleistocene)**—Unsorted to moderately sorted, sandy pebble to boulder gravel. Rounded to subrounded intrusive clasts and subrounded to subangular Belt-Purcell Supergroup clasts. Coarsely stratified to moderately stratified and locally interbedded with ice contact and some glaciolacustrine sediments. Soils of the Bonner series (Weisel and others, 1982). Thickness 30 m (100 feet) or more.

Qgg **Gravels of glacial origin (Pleistocene)**—Poorly rounded unsorted gravels; includes proglacial outwash and englacial drift deposits. Probably deposited by a post-Missoula floods advance of the Clark Fork ice tongue up the Clark Fork valley into a late Glacial Lake Missoula. Soils of the Pend Oreille series and Vay-Ardboo association (Weisel and others, 1982). Thickness 15 m (50 feet).

Qgl **Glacio-lacustrine silts of Lake Missoula (Pleistocene)**—Clayey to sandy silt, mostly in finely laminated to thin-bedded rhythmites with scattered dropstones. Preserved in tributary valleys of the Clark Fork that were protected from glacial and flood erosion. Glacial Lake Missoula reached a maximum elevation of about 1298 m (4260 feet) behind the Clark Fork ice dam. A paleomagnetic study of a measured section of over 50 m (160 ft) at the junction of Lightning Creek and East Fork just east of the map area showed the following: 1) rapidly filling and emptying cycles followed by longer periods of filling and emptying; 2) secular variation in the upper part of the section indicates a longer period of time than in the lower part; 3) cycles in the upper part of the section represent emptying of smaller late glacial lakes and smaller floods; and 4) the variation in declination is consistent with deposition of annual varves (Breckenridge and Othberg,1998, Meyer, 1999). The section is capped by a diamicton that may represent a late glacial advance. Soils of the Missoula silt loam (Weisel and others, 1982).

Qfg1 **Gravels of Missoula Floods, terrace 1 (Pleistocene)**—Moderately sorted pebble to boulder gravel. Generally lacking interstitial fines (boxwork texture). Moderately to stratified to unstratified depending on the depositional landform. In the Clark Fork quadrangle, the surface of this unit exhibits a series of giant current ripples deposited by the latest floods from Glacial Lake Missoula about 12,000 years ago. Forms the lowest of three terrace levels of flood gravel at about 630-640 meters (2065- 2100 feet) in the lower Clark Fork River valley. The upper two are not present in the Clark Fork quadrangle. Locally mantled by silt of the latest phases of glacial Lake Missoula that post-date episodes of catastrophic flooding. Soils of the Odenson and Wrencoe series (Weisel and others, 1982).

INTRUSIVE ROCKS

Tdu **Dikes, undivided (Eocene)**—Basic to intermediate composition dikes with euhedral biotite phenocrysts in biotite-plagioclase groundmass. Dikes clearly cross-cut Lightning Creek stock (Fillipone, 1993). Age of 51.7 +/- 0.07 from $^{40}Ar/^{39}Ar$ inverse isochron (Fillipone, 1993).

Kpd **Porphyritic dacite (Cretaceous)**—Hornblende-biotite dacite with plagioclase and subordinate quartz, hornblende, and biotite(?) phenocrysts in a K-spar rich aphanitic matrix. Exposed across ridge west of the Lightning Creek stock. A similar rock in the Scotchman Peak quadrangle to the east was dated as 89.8 +/- 0.1 Ma (total $^{40}Ar/^{39}Ar$ age; Fillipone, 1993). It is possible that both occurrences are related to the Lightning Creek stock although the latter appears younger.

Khbgd **Hornblende-biotite granodiorite (Cretaceous)**—Medium-grained hornblende-biotite granodiorite. Exposed across Lightning Creek as the Lightning Creek stock. Chemical analysis in Harrison and others (1972). Has ~500 m wide contact aureole with andalusite (Fillipone and Yin, 1994). Ages from biotite 71.7 Ma (K/Ar; recalculated from Miller and Engels, 1975) and 71.4+/- 0.7 Ma ($^{40}Ar/^{39}Ar$ plateau age; Fillipone and Yin, 1994) date cooling below biotite closure temperature during uplift (Fillipone, 1993). Age on hornblende of 75.7 +/- 0.3 Ma ($^{40}Ar/^{39}Ar$ integrated age over last 85.1 percent gas release; Fillipone and Yin, 1994) is likely close to emplacement age. Emplacement pressure was 4.6-5.5 kb (about 12-15 km depth) calculated from aluminum in hornblende (Fillipone and Yin, 1994).

Ymi **Mafic intrusive rocks, undivided (Middle Proterozoic)**—May include one or more of the varieties below (Yggd, Yqd, or Ygb). Most appear to be variants of the Moyie sills described by Bishop (1976) and are likely from both magma or differentiates intruded into the Prichard Formation at shallow levels closely following sedimentation (Cressman, 1989; Sears and others, 1998). Age of sills in Ype is probably close to U-Pb dates on zircons from Plains about 100 km southeast (1.47 Ga; Sears and others, 1998), or from near Kimberley, British Columbia about 160 km to the north (1.468 Ga; Anderson and Davis, 1995).

Yggd **Granophyric granodiorite (Middle Proterozoic)**—Fine-grained granophyric biotite granodiorite. Found only as single sill in *Ypf* southwest of Bee Top Mountain.

Yqd **Quartz diorite (Middle Proterozoic)**—Medium-grained biotite quartz diorite and biotite-hornblende quartz diorite; grades to tonalite and granodiorite. Found as mafic sills in upper parts of apparently differentiated mafic sills and as separate sills. Exhibits some granophyric intergrowth but not as extensive as in *Yggd* unit.

Ygb **Gabbro (Middle Proterozoic)**—Medium-grained hornblende gabbro. Appears to grade upward over short distance to *Yqd* with increasing quartz and decreasing hornblende.

BELT-PURCELL SUPERGROUP

Libby Formation (Middle Proterozoic)—Laminated to microlaminated dark gray to black argillite and white to light gray to pale green siltite, tan-weathering dolomitic siltite, oolite, and stromatolites. Highly resistant, chert-like material superficially resembling argillite commonly occurs as silicified mud-cracked tops of siltite-argillite couplets and mud chips, more rarely as apparently silicified argillite masses filling voids as if injected as fluid between bedding planes, inflating the strata. We followed Harrison and Jobin's (1963) subdivisions of the Libby because the same system was used to the east in Montana (Harrison and others, 1992) even though Kidder's (1992, 1998) subdivisions would be easier to maintain where the rocks are metamorphosed.

Yl3 **Libby Formation, member 3 (Middle Proterozoic)**—Microlaminated to laminated, dark gray to black argillite and light gray to white siltite interstratified with laminated pale green argillite and olive siltite that contain scattered layers of low domal stromatolites and thin (<10 cm) oolite beds. Mudcracked tops, mudchips, and small-scale cross-laminated bases common within the green siltite-argillite intervals. Olive siltite commonly dolomitic, weathering to characteristic tan color. Silicification varied, but especially common within pale green argillite and argillite mudchips. Similar to Kidder's (1992, 1998) member C except that it includes some carbonate near the base. Top eroded in map area so thickness unknown, but Harrison and Jobin (1963) reported 300 m (1000 feet) of their argillite, siltite, and dolomite member southeast of Clark Fork.

Yl2 **Libby Formation, member 2 (Middle Proterozoic)**—Laminated to less commonly microlaminated pale green to olive siltite and lighter green argillite. Siltite layers, typically a few cm thick with much thinner argillite caps, commonly display loaded bases and internal low angle cross-lamination. Deep mudcracks to 5 cm disrupt both siltite and argillite layers; some may be dewatering structures. Thin mudchips of pale green argillite ubiquitous and commonly silicified. Silicification of strata most common within the mm-thick argillite layers, although patchy silicification affects both siltite and argillite throughout unit. Upper part of unit contains multiple layers of low, domal stromatolites and purple, reddish weathering layers of oolite 1-10 cm thick. Upper contact placed above the carbonate beds and below a concentration of microlaminated to laminated white siltite and black argillite at base of *Yl3*. Unit similar to Kidder's (1992, 1998) member B but excludes gray argillite above and below that is included in B. Thickness about 100 m (330 feet); corresponds to calcareous member of Harrison and Jobin (1963), with reported thickness of 180 m (600 feet). Difference in thickness may be partly real and partly from difficulty of recognizing carbonate beds in poor exposures.

Yl1 **Libby Formation, member 1 (Middle Proterozoic)**—Laminated to microlaminated light gray to white to green siltite and dark gray to black argillite, and minor dolomitic gray siltite and stromatolites. Lamination mostly wavy and uneven. Commonly rusty weathering. Includes scattered and discontinuous gray siltite layers to 5 cm thick, with olive-colored cm-scale siltite beds more abundant in upper part and stromatolites at the top. Upper contact is placed above the concentration of microlaminated white siltite and black argillite. Similar to Kidder's (1992, 1998) member A but includes about 10 m (30 feet; Harrison and Jobin, 1963) of carbonate layers included in Kidder's member B. Thickness about 80 m (260 feet); corresponds to the argillite member of Harrison and Jobin (1963), who reported a thickness of 70 m (230 feet).

Ybo **Bonner Formation (Middle Proterozoic)**—Pink, red, and green fine- to medium-grained feldspathic quartzite, siltite, and argillite. Contains less K-spar than plagioclase; some plagioclase may be secondary but K-spar content is nevertheless low (5-6% versus 10-35% plagioclase). Characterized by 10-30 cm, tabular beds of flat-laminated pink quartzite with microlaminated to laminated red argillite caps. Internal lamination of quartzite beds commonly defined by discontinuous wisps of red argillite or thin red argillite mudchips. Some parting surfaces nearly covered with detrital muscovite flakes up to 4 mm across. Base is gradual transition from the underlying dark green and gray laminated siltite and argillite of *Yms6* with increasing abundance of 10-30 cm tabular light to medium green quartzite beds. These have well-rounded medium quartz grains, less feldspar than overlying red quartzite, and typically mm-thick, cracked argillite caps. Some green siltite with mm-thick black laminated caps also present. Well-rounded medium quartz grains also in wispy white sand lags typically less than one cm thick at bases of some red quartzite beds higher in the section. Interstratified with the red quartzite are intervals of laminated pink quartzite and red argillite. These zones decrease upwards from about half to about one quarter of the strata. At the top are very thin beds of green quartzite, overlain by several beds of white quartzite 5-10 cm thick with well-rounded medium grains. Upper white quartzite is less feldspathic than lower pink quartzite, and commonly contains 1 mm thick, 3 mm long silicified green argillite mudchips. Upper contact placed at lowest appearance of dark gray argillite and gray siltite of overlying *Yl1*. Zircons from a thin tuff at this contact about 40 km NE yielded an age of 1.401 Ga (U-Pb; Evans and others, 2000). Thickness is approximately 270 m (900 feet) (200-210 m, 650-700 feet; Harrison and Jobin, 1963). Equivalent to Bonner Quartzite in the Missoula area (Nelson and Dobell, 1961). Name changed from Harrison and Jobin's (1963) Striped Peak 4 to allow underlying strata to be assigned to Mt. Shields Formation.

Mount Shields Formation (Middle Proterozoic)—Red, green, and gray quartzite, red and green siltite, red, green, and gray to black argillite, and minor carbonate. Previously assigned to Striped Peak Formation (Harrison and Jobin, 1963) but reassigned here because strata are not markedly different from Mount Shields Formation mapped to the east in Montana by Harrison and others (1992).

Yms6 **Mount Shields Formation, member 6 (Middle Proterozoic)**—Rusty weathering, wavy to planar laminated, white to dark gray siltite and dark gray to black argillite, and rare gray to greenish gray quartzite in tabular beds up to 20 cm thick. Totally black argillite rare. Very thin dark gray argillite chips occur sparsely within some 10 cm dark gray argillite layers. Rare cm-wide, long, straight cracks and parallel cracks are present. Locally displays soft sediment deformation such as loading by siltite in lenses up to 20 cm across and 20 cm deep; some load structures exhibit possible channel erosion at their margins. Unit is a resistant, cliff-forming sequence in map area. Upper contact placed at lowest occurrence of tabular, green feldspathic quartzite of overlying Bonner Formation. Thickness approximately 150-180 m (500-600 feet). Mapped as Striped Peak 3 by Harrison and Jobin (1963) who estimated thickness as 90 m (300 feet). Unit equivalent to member 6 of Mount Shields Formation to the northeast (Harrison and others, 1992).

Yms4-5 **Mount Shields Formation, members 4 and 5 (Middle Proterozoic)**—Tan-weathering, bluish gray and bluish-green dolomitic siltite and white stromatolitic dolomite. Unit weathers recessively, forming topographic benches. Dolomitic siltite low in unit grades upward from carbonate-free siltite and argillite at top of *Yms1-3*. Rare 5-20 cm oolite layers occur near middle of unit. Near top is distinctive "boxwork" weathering pattern formed by etching out of resistant, mm-thick vertical and horizontal siliceous sheets along joints and bedding-plane partings. Algal mats typically flat, rarely as scattered, low algal domes. Upper contact placed at lowest occurrence of rusty weathering, resistant, laminated dark siltite and argillite of overlying *Yms6*. The oolite and boxwork part of unit is equivalent to member five of the Mount Shields Formation to the northeast (Harrison and others, 1992) but was not mapped separately here. Thickness approximately 180-230 m (600-750 feet) (120 m, 400 feet when mapped as Striped Peak 2 by Harrison and Jobin, 1963). Difference in thickness may be partly real and partly from different criteria in picking onset of carbonate beds in poor exposures.

Yms1-3 **Mount Shields Formation, members 1, 2, and 3 (Middle Proterozoic)**—Pale purplish red, fine-grained, flat-laminated quartzite, and green and red siltite and argillite; minor carbonate cement and stromatolites. Coarser grained and thicker bedded toward middle; mudcracks, mudchips, and ripple marks more common near base and top.

Lowest part (Mt. Shields member 1) characterized by fine- to very-fine-grained pink, flat-laminated quartzite in even beds 20-30 cm thick, capped by red argillite up to 3 cm thick. Base characterized by 10-20 cm beds of (green to pink, fine- to medium-grained quartzite and green siltite, both with mm-thick green argillite caps. Carbonate common near base in tan-weathering, laminated green dolomitic siltite and light green argillite intervals, as well as in a few thin tan-weathering quartzite beds. Rare low-angle cross beds present within quartzite beds. Pink quartzite with red argillite drapes become predominant up section, with minor interstratified mm laminated green siltite and light green argillite. Detrital muscovite flakes common on partings within the green quartzite. Mudcracks to 5 cm deep present within some beds; mudchips common.

Middle part (Mt. Shields member 2) characterized by flat-laminated 0.5-1.0 m beds of fine- to medium-grained quartzite that forms 15-30 m cliffs with blocky talus. Quartzite contains K-spar well in excess of plagioclase. Diffuse brown wisps of carbonate within the quartzite average a few cm in thickness and 10-15 cm in length. Uppermost part is medium-grained and distinctly coarser than all other quartzite in area except the thin sand lags near base of *Ybo*. Commonly rippled tops of the quartzite beds have thin red argillite drapes. Mudcracks and mudchips less common than in underlying or overlying intervals. Salt casts increase in abundance upward. Tan-weathering dolomitic siltite more common near top where several 10-20 cm thick stromatolitic beds are present.

Upper part (Mt. Shields member 3) characterized by thin pink quartzite beds, green and red siltite and argillite, and abundant salt casts, mudcracks, and mudchips. Salt crystal casts range in size from a few mm to 2 cm hollow hopper crystal casts. Quartzite is most abundant in lower part; distinctive dark green siltite beds more abundant in upper part. Upper contact of *Yms1-3* placed at lowest occurrence of non-resistant dolomitic siltite of overlying *Yms4-5*. Overall thickness of *Yms1-3* uncertain, but approximately 150 m (500 feet) (180 m, 600 feet; Harrison and Jobin, 1963) who previously mapped as Striped Peak 1. Equivalent to lower three members of the Mount Shields Formation mapped to the northeast (Harrison and others, 1992).

Shepard Formation (Middle Proterozoic)—Dolomitic green siltite and light green argillite, dolomitic very fine-grained quartzite, and dark gray laminated and thinly laminated siltite and argillite. Occupies same stratigraphic level as top of Wallace Formation previously mapped here (Harrison and Jobin, 1963) and to the south (Lewis and others, 1999, 2002). Renamed Shepard Formation here because it is not markedly different from Shepard Formation at its type locality and is separated from the carbonate-bearing pinch and swell strata typical of Wallace Formation as found near Wallace, Idaho by carbonate-free strata.

Ysh2 **Shepard Formation, member 2 (Middle Proterozoic)**—Rusty weathering, even and thinly laminated white, green, and dark gray siltite and dark gray to black argillite, and white siltite and quartzite. Lower part is unevenly laminated light green to white siltite with thin gray to commonly black argillite caps. Rare beds up to 20 cm thick of very fine-grained white quartzite contain scattered black mudchips. Rare curved cracks up to 5 cm deep on bedding plane surfaces resemble fluid-escape structures. Up section are 5-10 cm beds of slightly dolomitic, dark green siltite interstratified with uneven laminae and couplets of dark green siltite and pale green argillite, identical to lithologies present in *Ysh1*. Small stromatolites rare but present in this interval. Uppermost part of unit unevenly laminated medium greenish gray siltite and pale greenish gray argillite similar to lower lithologies, but lacking trace of carbonate and including rare black argillite. Includes rare cm thick beds of light green quartzite and green, dm-scale siltite beds. Some cm-scale siltite is discontinuous and occurs in lenses, apparently as a result of soft-sediment compaction. Contact with overlying Mt Shields Formation is lowest occurrence of cm-scale, very fine-grained pink quartzite with red argillite caps or muscovite (something) green quartzite. Thickness about 150-240 m (500-800 feet) (120 m, 400 feet; Harrison and Jobin, 1963). Previously mapped as the laminated argillite and siltite member (Wallace 5) by Harrison and Jobin (1963). Equivalent to upper Wallace member 3 to the south (Lewis and others, 2002), to upper part of the Shepard Formation in Western Montana (Lemoine and Winston, 1986), and to argillite of Half Moon Lake to the north (Miller and Burmester, 2003).

Ysh1 **Shepard Formation, member 1 (Middle Proterozoic)**—Tan-and brown-weathering, dolomitic green siltite and light green argillite with minor interstratified 10-20 cm beds of dolomitic, very fine-grained quartzite. Argillite and siltite are unevenly and thinly laminated, microlaminated, and in thin, graded beds (uneven couplets). Uneven laminations of dark green siltite and pale green argillite at the base pass upward into intervals of thicker uneven couplets of dark green siltite and pale green argillite. Weathered outcrops are distinctive brown (siltite) and tan (argillite). Dolomite content increases up section. Dolomitic quartzite layers to 20 cm thick and rare low domal stromatolite horizons scattered throughout unit. Layers of flat-pebble rip-up conglomerate to 5 cm thick present near middle of unit are commonly associated with centimeter-wide straight cracks that penetrate bedding to 10 cm depths in siltite and argillite layers. Bedding locally discontinuous in middle and upper parts, with thin gray limestone pods and silty and sandy ripple trains within the thicker argillites. Isolated "starved" ripples common. Upper part is uneven siltite and argillite couplets and uneven laminations of slightly dolomitic siltite and argillite. Upper contact gradational; best placed above highest dolomitic siltite or highest thick dolomitic laminated unit. Thickness about 400 m (1300 feet) (300 m, 1000 feet; Harrison and Jobin, 1963). Previously mapped as the upper calcareous member (Wallace 4) by Harrison and Jobin (1963). Equivalent to upper Wallace member 2 to the south (Lewis and others, 2002), to lower part of Shepard Formation present in western Montana (Lemoine and Winston, 1986) and all rocks assigned to Shepard Formation to the north (Miller and Burmester, 2003).

Yhm **Argillite of Howe Mountain (Middle Proterozoic)**—Rusty weathering gray and green siltite and dark green and gray argillite, subordinate pale green fine-grained quartzite, and minor carbonate. Corresponds to upper Wallace member 1 to the south (Lewis and others, 2002). Name changed to avoid confusion with upper Wallace that includes Shepard Formation interval elsewhere in Idaho. Corresponds to Snowslip Formation to the north (Burmester, 1986) and east (Harrison and others, 1992) but not so named because it lacks redbeds present in Snowslip Formation there. Named after Howe Mountain, northwest of Clark Fork, Idaho. Subdivided into three units where exposure adequate. Lower unit corresponds closely to the argillite member (Wallace 2) of Harrison and Jobin (1963). Upper two units correspond closely with the argillite, siltite, and limestone member (Wallace 3) of Harrison and Jobin (1963). Age of top of unit is approximately that of the Purcell Lava, 1.44 Ga (Evans and others, 2000), which occur close to the Snowslip-Shepard contact to the northeast and east (Harrison and others, 1992). Thickness about 760 m (2500 feet).

Yhm3 **Argillite of Howe Mountain, member 3 (Middle Proterozoic)**—Dark green siltite and light green to black argillite in microlaminae and wavy or uneven couplets, and thicker green siltite. Decimeter-scale green siltite beds are more common than in *Yhm2* and *Yhm1* black argillite less common. Large, straight-sided cracks, visible on bedding plane surfaces, commonly disrupt lamination to a depth of several cm in the green beds. These are interpreted as water-escape structures; only near the upper contact are true desiccation cracks and mudchips common. Top is gradational into overlying *Ysh1* with increase in carbonate content in the interval of microlaminated green siltite and argillite. Contact placed arbitrarily at lowest appearance of significant carbonate within laminated siltite and argillite beds. Thickness about 300-330 m (1000-1100 feet).

Yhm2 **Argillite of Howe Mountain, member 2 (Middle Proterozoic)**—Planar-laminated couplets of greenish gray siltite and dark gray argillite, and green decimeter-scale gray siltite beds. Characteristic planar parallel lamination widespread at this stratigraphic level (Burmester, 1986; Lewis and others, 1999, 2000). Similar in plane parallel lamination to the "lined unit" of the Prichard Formation (*Yph*) but not as sulfide-rich or rusty weathering. Upper contact placed at top of thick interval of planar laminated siltite-black argillite. Thickness about 150 m (500 feet). Mapped as part of Wallace by Harrison and Jobin (1963).

Yhm1 **Argillite of Howe Mountain, member 1 (Middle Proterozoic)**—Uneven couplets and microlaminae of gray to green siltite and black, to less commonly green argillite. Some black microlaminated zones show soft sediment deformation. Includes thin zone of planar microlaminated siltite-black argillite like *Yhm2* about 200 m (600 feet) below top. Upper contact placed at base of thick section of planar laminated siltite and black argillite. Thickness about 300 m (1000 feet).

Yw **Wallace Formation (Middle Proterozoic)**—Pinch and swell couples and couplets of gray, tan-weathering carbonate to dolomitic, very fine-grained quartzite or siltite and black argillite, lesser amounts of calcareous and non-calcareous white quartzite and dolomitic siltite, and rare stromatolites. Characterized by graded couplets and couples exhibiting pinch and swell sediment type of Winston (1986) in which scours and loads of quartzite cut or deform subjacent black argillite. Black argillite caps commonly contain physically folded siltite- or quartzite-filled cracks that taper downward. On bedding plane surfaces, the cracks are generally discontinuous and sinuous, occurring as isolated parallel or three-pointed star "birdfoot" cracks. Lower part contains abundant gray to tan weathering siltite and black argillite pinch and swell couplets. Beds of molar-tooth dolomite occur within 10-20 cm and beds of conchoidally fracturing brown weathering dolomite to 20 cm are locally common. Vertical calcite ribbons and horizontal pods accompany molar tooth structures in some strata over 20 cm thick throughout unit. A thin interval of green, dolomitic siltite and argillite and white quartzites that closely resembles *Yh* is present above the lowest pinch and swell interval. White quartzite occurs as lenses in harmonically cross-stratified tabular beds 15-30 cm thick; thinner white quartzites a few cm thick commonly interbedded with non-resistant vertical joints into a distinct "segmented" appearance. Cycles of 20-30 cm thick white quartzites overlain by intervals of microlaminated black argillite are common in upper part. Rare horizons of stromatolites occur in middle, and one thin stromatolite layer occurs near upper contact in the map area. Upper contact placed above highest occurrence of pinch and swell couplets. Thickness on the order of 790 m (2600 feet). Unit is upper part of the lower calcareous member (Wallace 1) of Harrison and Jobin (1963). Equivalent to the middle member of Wallace as mapped by Harrison and others (1986) and Lewis and others (2002). Middle dropped from name here because upper and lower Wallace units have been renamed.

Yh **Helena Formation (Middle Proterozoic)**—Cyclic couplets and couples of white quartzite to tan-weathering dolomite or dolomitic siltite, with associated massive green siltite and thinly laminated wavy green siltite and argillite, dolomitic white quartzite and dolomite (calcarenite) and calcite pods. Lower part predominantly thin, wavy laminae to couplets of green siltite and light green argillite. Upper part dominated by siliciclastic to carbonate cycles. White calcitic quartzite, commonly 10-20 cm in thick, overlain by tan-weathering, green silty dolostone or dolomitic siltstone. Quartzite typically exhibits vertical segmentation gaps where carbonate has been removed. Brown-weathering, gray, conchoidally-fracturing dolostone scattered throughout; gray limestone with characteristic vertical "molar-tooth" structures common. Higher in unit, oblong horizontal carbonate "pods" are common within the silty dolostone. Gray quartzite with black argillite caps occur in upper part; black argillite only appears as chips in this beds scattered but become more common near top. Upper contact placed at lowest concentration of pinch and swell couplets with black argillite tops. Thickness uncertain but on the order of 150-240 m (500-800 feet). Unit corresponds to the lower Helena Formation to the east (Harrison and others, 1992). Lowest 100 m (330 ft) possibly equivalent to Empire Formation. Zircons from a tuff in the upper Helena about 170 km ENE yielded a U-Pb date of 1.454 Ga (Evans and others, 2000). Unit is lower part of the lower calcareous member (Wallace 1) of Harrison and Jobin (1963). Equivalent to the lower member of Wallace as mapped by Harrison and others (1986) and Lewis and others (2002).

Ysr **St. Regis Formation (Middle Proterozoic)**—Pale purple to gray siltite, argillite and quartzite, and light green siltite and gray argillite or dark green siltite and light green argillite couplets. Greens more common near top. Typically mudcracked 1 cm siltite and argillite couplets, but with very thin (2-5 cm) and rare thin (10-20 cm) tabular fine-grained quartzite beds with green argillite caps, similar to those of the Revett Formation. Tabular quartzites particularly abundant near base. Conspicuous layers of mudchips to 5 cm thickness ubiquitous. Thin (mm-thick) wisps of brown-weathering dolomitic silt are similar to those within the siltite-argillite couplets in upper part. Wavy couplets and couples with purple siltite and black argillite tops up to 20 cm also common near top. Upper contact placed above highest cracked and mudchip-bearing purple siltite and argillite, where gray siltite and argillite laminae and couplets of overlying *Yh* replace the purple. Thickness about 240-290 m (800-950 feet) (180-300 m, 600-1000 feet; Harrison and Jobin, 1963). Difference in thickness apparently real because Harrison and Jobin (1963) included some purple strata in their lower calcareous member (Wallace 1).

Yr **Revett Formation (Middle Proterozoic)**—Resistant white quartzite with green siltite and argillite, commonly as mm to cm green argillite caps. Most beds tabular, although wedge-shaped or discontinuous beds are common. Some quartzite vitreous or sericitic; most feldspathic with subequal potassium feldspar and plagioclase, each comprising 15-20% of the rock. Sub-millimeter orange-brown spots common. Rippled tops and tabular planar cross lamination more common than trough cross lamination; much is flat laminated. Quartzite is commonly of the discontinuous sediment type (Winston, 1986). Mudcracks and mudchips common in argillitic tops throughout. Lower part consists of multiple beds of feldspathic quartzite more than 30 cm thick (cosets of thick sets; McKee and Weir, 1963). Middle part is a less-resistant interval with lower concentration of quartzite and more mudcracked couplets of green siltite and argillite. Upper part consists of more cosets of thick sets of resistant quartzite, with thin cracked green argillite caps. Large load casts to 20 cm deep and 30 cm across (ball and pillow structures) are especially abundant in upper part, although present at bases of some quartzite beds throughout. Upper contact placed above highest cosets of thick sets of quartzite. Placement of contacts likely different from previous mapping because we followed Hayes (1983) and Hayes and Einaudi (1986) in using physical attributes of quartzite and not color to specify the unit's contacts. Thickness about 550-590 m (1800-1950 feet) (610 m, 2000 feet; Harrison and Jobin, 1963).

Prichard Formation (Middle Proterozoic)—White to gray siltite, white to gray to black argillite, and white to gray feldspathic quartzite. Siltite typically rusty weathering and planar laminated with black argillite tops, some with white argillite tops. Bar code like patterns formed by siltite and argillite couplets persist over 100 kilometers (Huebschman, 1973). These "marker beds" were used by Cominco for correlation across large areas (Hamilton and others, 2000). Rusty nature comes from abundant sulfides, commonly pyrrhotite. Average quartzite has 21 per cent feldspar (Cressman, 1985) and is lighter weathering in decimeter beds. Unit designations follow subdivision of Cressman (1985) from near Plains, Montana, about 90 km to the southeast.

Ypg **Prichard Formation, member g (Middle Proterozoic)**—Gray to white feldspathic quartzite and dark gray argillite. Fine- to very fine-grained quartzite as decimeter, rarely thicker beds. Ripple cross lamination, rippled tops, some finer grained, and (mud?) cracked argillite surfaces present though not abundant. Interlayered with platy, even parallel siltite. Top not exposed in map area but thickness approximately 530-590 m (1750-1950 feet) is similar to thickness to the southeast (500 m; 1640 feet; Cressman, 1985) and north (610 m, 2000 feet; Burmester, 1986).

Ypf **Prichard Formation, member f (Middle Proterozoic)**—Rusty weathering, even parallel laminated, gray siltite and dark gray argillite, and minor lighter quartzite. Contains metamorphic biotite and chloritoid. Unit also reported to contain argillite pebble conglomerate to the southeast (Cressman, 1985). Top placed below concentration of feldspathic quartzites of *Ypg*. Thickness unknown locally; swath mapped across Lightning Creek requires 3000 m. Given that overlying and underlying units are not anomalously thin relative to other areas, this thickness does not come at the expense of those. Judging from thickness of about 975-1100 m to the southeast (3200-3600 feet; Cressman, 1985) and 900 m to the north (3000 feet; Burmester, 1986), unit is repeated by mapped and unmapped, down to the west normal faults and perhaps unmapped northwest-vergent thrust faults.

Ypfq **Prichard Formation, member f quartzite (Middle Proterozoic)**—Light gray weathering medium-grained quartzite. Only subdivided locally. One sample low in *Ypf* lacked K-spar and had approximately 5-10 percent plagioclase. Two samples from a thick quartzite interval higher in *Ypf* have what appears to be late (secondary or authigenic) K-spar, possibly due to intrusion of the Lightning Creek stock and related dikes. Locally contains brown weathering carbonate concretions to 30 cm in diameter.

Ype **Prichard Formation, member e (Middle Proterozoic)**—Light gray to white weathering siltite and quartzite and darker argillite. Decimeter siltite dominates over very feldspathic quartzite, but both exhibit features of current traction such as rippled tops and ripple cross lamination. Some quartzite beds coarser grained and less feldspathic than typical of the Prichard. Two samples lack K-spar and have approximately 8-10 percent plagioclase. These are poorly sorted but contain very well-rounded, medium sand-sized quartz grains. Better sorted, similarly shaped large grains form matrix of rare, decimeter-thick intraclast conglomerate beds at a few horizons. Top placed above highest zone of quartzite with abundant current features and below thick section of uniformly parallel laminated rusty weathering siltite. Thickness approximately 700 m (2300 feet) excluding 300 m of sills (825 m, feet excluding sills; Cressman, 1985).

STRUCTURE

Structures in the area include folds, faults and tilted fault blocks. Overall, Belt strata homoclinally dip to the east. Dips are gentle over most of the area, but are steep locally west of Clark Fork. The major structures are described below.

EARLY THRUST FAULTS

We found bedding plane parallel shears on Antelope Mountain east of Clark Fork, although did not determine kinematics. These may be related to the northwest vergent thrust faults mapped in and around mines north of Clark Fork, which appear to be earlier than the steep, extensional faults that control mineralization (Anderson, 1947). They likely date from Cretaceous contraction. Although these faults have small displacement, there may be others that are not well exposed with more displacement that duplicate some parts of the section, specifically of the Shepard Formation and enclosing strata west of Clark Fork, and *Ypf* across and west of Lightning Creek. One candidate is a possible fault along Lightning Creek into which the Lightning Creek stock intruded. If true, lack of fabric in the stock indicates that thrusting had ceased there by 74 Ma.

PACKSADDLE FAULT

Harrison and Jobin (1963, 1965) showed this fault along Johnson Creek projecting north-northeast to the Hope fault and apparently interpreted it as one of many "block faults" that accommodated block tilting. However, it is spatially associated with anomalously steep dips so possibly accommodated shortening inside a large-scale eastward vergent syncline defined by the shallower dips to the east and steeper dips to the west. Alternatively, it may be part of a (back?) thrust system.

HOPE FAULT

The Hope fault extends southeastward from the Purcell trench on the west toward Thompson Falls, Montana. Its age and kinematics have been discussed by Harrison and others (1972) and Fillipone and Yin (1994). Its activity during deposition of the Prichard may account for difference in thickness of mafic sills across it (Harrison and Jobin, 1963). The long, straight trace of the fault is suggestive of transcurrent movement, but structural evidence for such is lacking (Fillipone, 1993). The only documented movement has been dip slip (Fillipone, 1993), with it acting in conjunction with the (southern) Purcell trench fault during the Eocene (Fillipone and Yin, 1994; Doughty and Price, 2000). Although post-Eocene movement has not been documented, the geomorphic expression of the fault is notable. Also, a number of historical seismic events have been felt to the southeast along the trace in Trout Creek and Thompson Falls, Montana.

REFERENCES

Anderson, A.L., 1947, Lead-silver deposits of the Clark Fork District, Idaho: U.S. Geological Survey Bulletin 944-B, 117 p.
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.
Bishop, D.T., 1976, Petrology and geochemistry of the Purcell sills, Boundary County, Idaho and adjacent areas, Ph.D. thesis, University of Idaho, 147 p.
Breckenridge, R.M., and K.L. Othberg, 1998, Chronology of glacial Lake Missoula floods: paleomagnetic evidence from Pleistocene lake sediments near Clark Fork, Idaho, Geological Society of America, Abstracts with Programs, v. 30, p. 5.
Burmester, R.F., 1986, Preliminary geologic map of the Leonia area, Idaho and Montana, U.S. Geological Survey Open File Report OF-86-554, 13 p. and 1:48,000-scale map.
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 (Middle Proterozoic) and the early development of the Belt Basin, Washington, Idaho, and Montana: U.S. Geological Survey Professional Paper 1490, 80 p.
Doughty, P.T., and R.A. Price, 2000, Geology of the Purcell Trench rift valley and Sandpoint Conglomerate: Eocene en echelon normal faulting and synrift sedimentation along the eastern flank of the Priest River metamorphic complex, northern Idaho: Geological Society of America Bulletin, v. 112, no. 9, p. 1356-1374.
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.
Fillipone, J.A., 1993, Tectonic and thermochronologic evolution of the Cabinet and Selkirk Mountains, northwest Montana and northern Idaho: Ph.D. dissertation, Los Angeles, California, University of California, 341 p.
Fillipone, J.A., and An Yin, 1994, Age and regional tectonic implications of Late Cretaceous thrusting and Eocene extension, Cabinet Mountains, northwest Montana and northern Idaho: Geological Society of America Bulletin, v. 106, p. 1017-1032.
Hamilton, J.M., R.G. McEachern, and O.E. Owens, 2000, A history of Geological investigations at the Sullivan deposit, *in* Lydon, J.W., Trygve Hoy, J.F. Slack, and M.E. Knapp, eds., The Geologic Environment of the Sullivan Deposit, British Columbia: Geological Association of Canada, Mineral Deposits Division, Special Publication 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. K1-K38.
Harrison, J.E., and D.A. Jobin, 1965, Geologic map of the Packsaddle Mtn. quadrangle, Idaho: U. S. Geological Survey Geological Quadrangle Map GQ-375, scale 1:62,500.
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.
Harrison, J.E., A.B. Griggs, and J.D. Wells, 1986, Geologic and structure maps of the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-A, scale 1:250,000.
Harrison, J.E., M.D. Kleinkopf, and J.D. Obradovich, 1972, Tectonic events at the intersection between the Hope fault and the Purcell trench, northern Idaho: U.S. Geological Survey Professional Paper 719, 24 p.
Hayes, T.S., 1983, Geologic studies on the genesis of the Spar Lake strata-bound copper-silver deposit, Lincoln County, Montana: Ph.D. Dissertation, Stanford University, 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. -1931.
Huebschman, R.P., 1973, Correlation of fine carbonaceous bands across a Precambrian stagnent basin: Journal of Sedimentary Petrology, v. 43, p. 688-699.
Kidder, D.L., 1992, Stratigraphy and sedimentology of the Libby Formation, Belt Supergroup (Middle Proterozoic) of Montana and Idaho, U.S.A.: Contributions to Geology, University of Wyoming, v. 29, p. 119-132.
Kidder, D.L., 1998, The Libby Formation and its significance with respect to changing sedimentation patterns in the upper Belt Supergroup, *in* Berg, R.B., ed., Belt Symposium III: Montana Bureau of Mines and Geology Special Publication 112, p. 104-112.
Lane, E.W., and others, 1947, Report of the subcommittee on sediment terminology: Transactions of the American Geophysical Union, v. 28, p. 937-938.
Lemoine, S.R., and D. 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, 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 GM-33, scale 1:100,000.
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, USGS Open File Report OF-99-390. http://wrgis.wr.usgs.gov/open-file/of99-390/OF99-390.PDF
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.
Meyer, S.E., 1999, Depositional history of pre-late and late Wisconsin outburst flood deposits in northern Washington and Idaho: an analysis of flood paths and provenance: Washington State University, M.S. thesis, 91 p.
Miller, F.K., and R.F. Burmester, 2003, Geologic Map of the Bonners Ferry 30' x 60' Quadrangle, Idaho and Montana, U.S. Geological Survey Miscellaneous Field Studies Map MF-2426.
Miller, F.K., and J.C. Engels, 1975, Distribution and trends of discordant ages of the plutonic rocks of northeastern Washington and northern Idaho: Geological Society of America Bulletin, v. 86, p. 517-528.
Nelson, W.H., and J.P. Dobell, 1961, Geology of the Bonner quadrangle, Montana: U.S. Geological Survey Bulletin 111-F, p. 189-235.
Sears, J.W., K.R. Chamberlain, and S.N. Buckley, 1998, Structural and U-Pb geochronological evidence for .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., P.M. Hartwig, S.D. Keirn, and B.J. Turner, 1982, Soil Survey of Bonner County Area, Idaho, Parts of Bonner and Boundary Counties: United States Department of Agriculture, Soil Conservation Service, 201 p.
Winston, Don, 1986, Sedimentology of the Ravalli Group, middle Belt carbonate, and Missoula Group, Middle Proterozoic 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. 85-124.

ACKNOWLEDGMENTS

Accommodations at the University of Idaho Field Campus in Clark Fork and the assistance of the managers, Brian Ward and Ken Kinucan, are greatly appreciated. The U.S. Geological Survey Minerals Program in Spokane, Washington, provided vehicle and trailer support.

Published and sold by the Idaho Geological Survey
University of Idaho, Moscow, Idaho 83844-3014