Geologic Map of the Scotchman Peak Quadrangle, Bonner County, Idaho

Compiled and Mapped by
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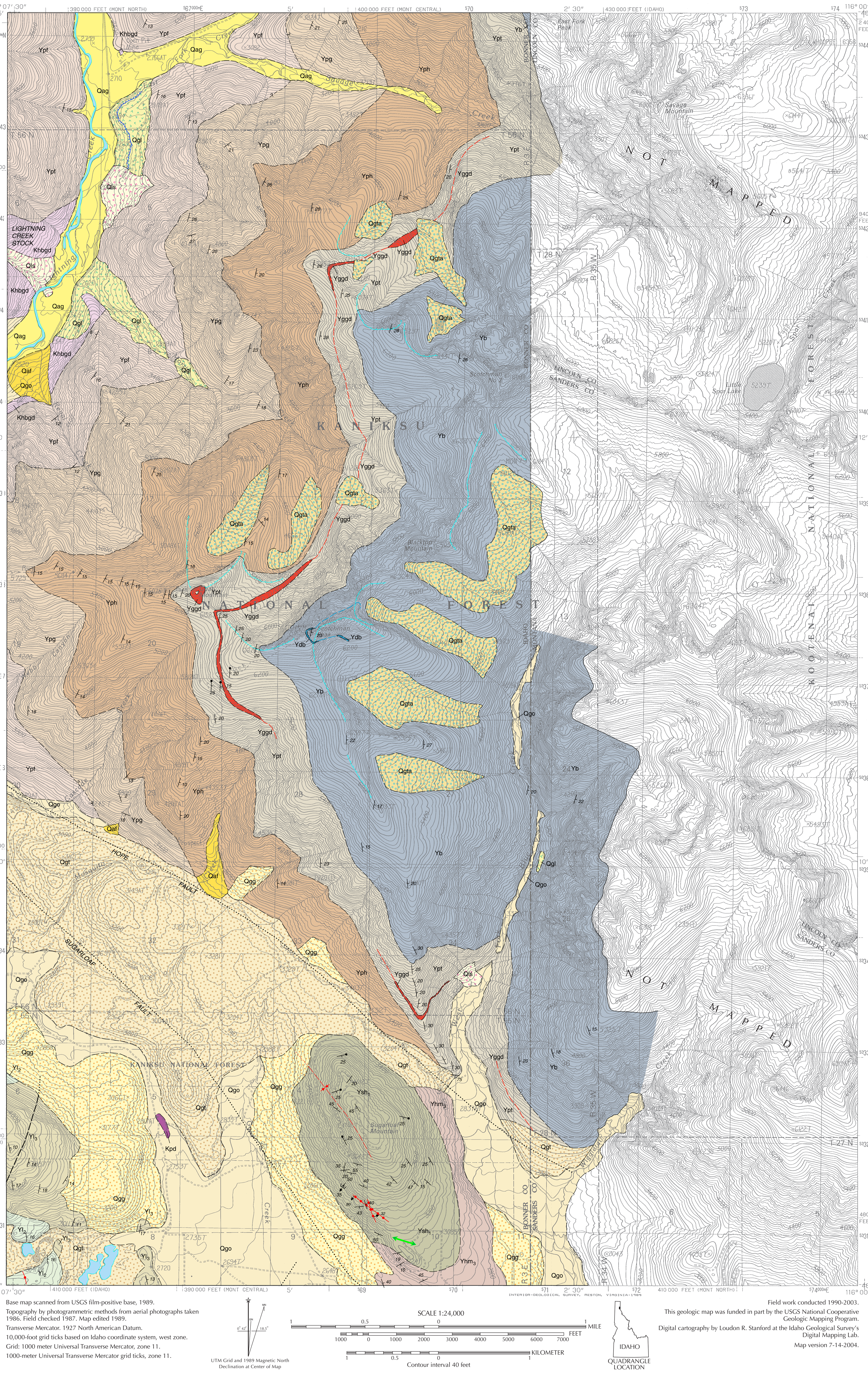
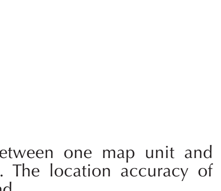
2004

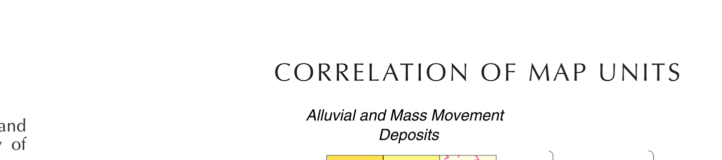


Base map scanned from USGS film-positive base, 1989.
Topography by photogrammetric methods from aerial photographs taken 1986. Field checked 1987. Map edited 1989.
Transverse Mercator. 1927 North American Datum.
10,000-foot grid ticks based on Idaho coordinate system, west zone.
Grid: 1000 meter Universal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



UTM Grid and 1989 Magnetic North Declination at Center of Map

SCALE 1:24,000

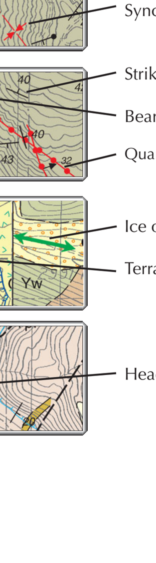


Contour interval 40 feet

QUADRANGLE LOCATION

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 7-14-2004.

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.

Fault: High-angle fault; dashed where approximately located; dotted where concealed.

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

Fold axis: approximately located; dotted where concealed.

Syncline.

Strike and dip of bedding.

Bearing and plunge of small fold axis.

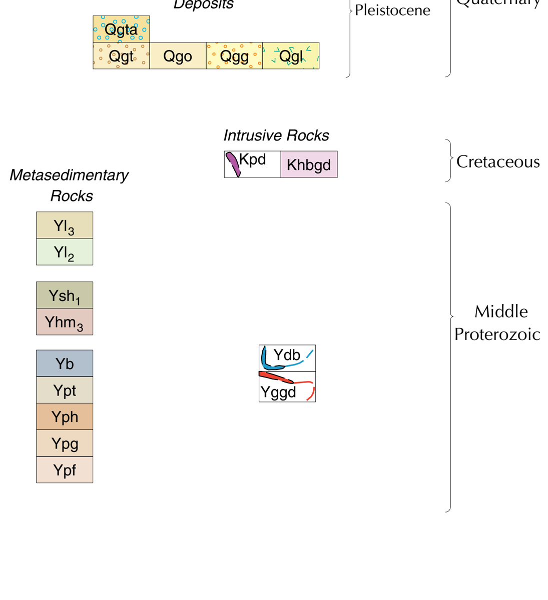
Quartz vein: Arrow indicates dip.

Ice or flood gap.

Terrace scarp.

Headwalls of alpine cirques.

CORRELATION OF MAP UNITS



INTRODUCTION

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 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.

The oldest and most abundant rocks in the Scotchman Peak quadrangle are low metamorphic grade metasedimentary rocks of the Belt-Purcell Supergroup, Precambrian in age, some of which host penecontemporaneous intrusive sills. Plutonic rocks of Cretaceous age also are present as intrusions within the Belt Supergroup. Sediments in the lower elevations, along valley walls, and below the high mountain cirques date from Pleistocene glaciation and catastrophic floods from glacial Lake Missoula through the Clark Fork valley. 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).

ALLUVIAL AND MASS MOVEMENT DEPOSITS

Qaf **Alluvial fan deposits (Holocene)**—Mixed pebble- to cobble gravel deposited as fans at the mouth of small 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 variable 1-10 m (3-33 feet).

Qag **Alluvial gravel deposits (Holocene)**—Sandy cobble to boulder gravels in modern flood plain of Lightning Creek drainage. 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).

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. Soils of the Bonner and Dufort series (Weisel and others, 1982). Variable thickness as much as 10's of m (100 feet).

GLACIAL AND FLOOD-RELATED DEPOSITS

Qgta **Alpine till deposits (Pleistocene)**—Coarse, blocky, unsorted sandy cobble to boulder till 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 Maximum in the Cabinet mountains. Soils of the Vay-Ardtoo association (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 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 or more (100 feet).

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 tongue up the Clark Fork valley into a late glacial Lake Missoula. Soils of the Pend Oreille series and Vay-Ardtoo 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. A paleomagnetic study of a measured section of over 50 m (160 ft) at the junction of Lightning Creek and East Fork show 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 Mission silt loam (Weisel and others, 1982).

INTRUSIVE ROCKS

Kpd **Porphyritic dacite (Cretaceous)**—Hornblende-biotite dacite with quartz, plagioclase, biotite, and hornblende phenocrysts in a K-spar rich aphanitic matrix. Exposed west of Sugarloaf Mountain in veined "dike fault" of Harrison and Jobin (1963) where it was dated as 89.8 +/- 0.1 Ma (total $^{40}Ar/^{39}Ar$ gas age; Fillipone, 1993). It is possible that it is 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) 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 from ^{40}Ar-^{39}Ar (integrated age over last 85.1 percent gas released; Fillipone and Yin, 1994) is likely closer 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).

Ydb **Diabase (Middle Proterozoic)**—Fine-grained hornblende-plagioclase mafic intrusion. Occurs as thin sill low in *Yb* on Scotchman Peak. Rock is jade green and, although highly altered (chlorite+epidote+calcite), contains relict hornblende. Must be younger than synsedimentary Moyie sills that intruded much lower in the Prichard Formation and are dated around 1.47 Ga (Anderson and Davis, 1995; Sears and others, 1998). Possibly related to the Purcell Lava. Rhyolite in the Purcell lava about 100 km NNE is 1.443 Ga (Evans and others, 2000).

Yggd **Granophyric granodiorite (Middle Proterozoic?)**—Fine-grained granophyric granodiorite. Found as sill low in *Ypt* on top of Goat Mtn and at same stratigraphic level southeast and west to northwest of Scotchman Peak. Well-developed micrographic (granophyric) texture. Contains about 2 percent chloritized biotite and similar amounts of muscovite, in addition to secondary epidote and sericite. Assigned a Cretaceous age by Harrison and Jobin (1963) but granophyric and concordant nature more similar to Proterozoic sills elsewhere.

BELT-PURCELL SUPERGROUP

Libby Formation (Middle Proterozoic)—Laminated to microlaminated white to light gray to pale green siltitite and dark gray to black argillite, tan-weathering dolomitic siltite, oolite, and stromatolites. Highly resistant, chert-like material superficially resembling argillite commonly occurs as silicified mud chips and mud-cracked tops of siltite and argillite, 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.

Yl_3 **Libby Formation, member 3 (Middle Proterozoic)**—Microlaminated to laminated, light gray to white siltite and dark gray to black argillite interstratified with laminated olive siltite and pale green argillite, with scattered carbonate 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 and 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 (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, Idaho.

Yl_2 **Libby Formation, member 2 (Middle Proterozoic)**—Laminated to less commonly microlaminated pale green to olive siltite and lighter green argillite. Siltite layers, a few cm thick with much thinner argillite caps, commonly display loaded bases and internal low-angle cross-lamination. 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 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 punky, recessively weathering layers of oolite 1-10 cm thick. Upper contact placed above the concentration of these carbonate beds and below a concentration of microlaminated to laminated white siltite and black argillite at base of Yl_3. Unit similar to Kidder's (1992, 1998) member B but excludes gray argillite above and below that is included in B. Base not exposed in quadrangle but 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.

Ysh_1 **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, and very fine-grained quartzite. Siltite and argillite are unevenly and thinly laminated, microlaminated, and in thin, graded beds (uneven couplets). Rocks exposed on Sugarloaf Mountain too disrupted to reveal internal stratigraphic order, but on Clark Fork quadrangle to the west even 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, with dolomite increasing upward. Weathered outcrops are distinctive brown (siltite) and tan (argillite). Scattered throughout are dolomitic quartzite layers to 20 cm thick and rare low domal stromatolite horizons. Bedding locally discontinuous, with thin gray limestone pods and silty and sandy ripple trains within the thicker argillites. Isolated "starved" ripples common. Top not exposed. Thickness in the Clark Fork quadrangle 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). Renamed 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. Equivalent to upper Wallace member 2 to the south (Lewis and others, 2002), 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_3 **Argillite of Howe Mountain, member 3 (Middle Proterozoic)**—Dark green siltite and light green to black argillite as microlaminae and wavy or uneven couplets, and thicker green siltite. Decimeter-scale green siltite beds common; black argillite caps decrease upward. 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 top are true desiccation cracks and mudchips common. In the Clark Fork quadrangle to the west top is gradational into overlying Ysh_1 with increasing carbonate content in the interval of microlaminated green siltite and argillite. Contact in this area either covered or faulted. Thickness in the Clark Fork quadrangle about 300-330 m (1000-1100 feet). Corresponds to top of the argillite, siltite, and limestone member (Wallace 3) of Harrison and Jobin (1963) and top of 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 top of Snowslip Formation to the north (Burmester, 1986) and east (Harrison and others, 1992) but not so named because it and lower members lack redbeds present in Snowslip Formation there. Named after Howe Mountain, northwest of Clark Fork, Idaho, where it was subdivided into three units. Age of the top of unit is approximately that of the Purcell lavas (see *Ydb*), which occur close to the Snowslip-Shepard contact to the northeast and east (Harrison and others, 1992). Thickness about 760 m (2500 feet).

Yb **Burke Formation (Middle Proterozoic)**—Green siltite and argillite and gray to white quartzite. Siltite beds typically 10-20 cm with macroscopic magnetite octahedra. Argillite partings commonly dark green, some lighter green. Mudcracks and chips common throughout. Flat-laminated fine-grained, gray to white quartzite in 20-50 cm beds, some with rippled tops and cross lamination, are present toward bottom and increase upward. Nearly spherical manganese carbonate concentrations common within them weather to round or ellipsoidal spots or cavities to 8 cm across. Purple-banded quartzites in beds 20-50 cm in thickness common in uppermost part. Upper contact outside map area placed at base of lowest cosets of thick sets (McKee and Weir, 1963) of quartzite of the Revett Formation. Thickness uncertain within the area, but approximately 1000 m (3300 feet) (980 m, 3200 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. Rusty nature comes from abundant sulfides, commonly pyrrhotite. Average quartzite has 21 per cent feldspar (Cressman, 1985) and is lighter weathering in decimeter beds. Bar code-like patterns formed by light and dark siltite in intervals 8 cm to 4.5 m thick persist regionally over 100 kilometers (Huebschman, 1973). These "marker beds" were used by Cominco for correlation across large areas (Hamilton and others, 2000). With exception of *Ypt*, unit designations follow subdivision of Cressman (1985) from near Plains, Montana, about 90 km to the southeast.

Ypt **Prichard Formation, transition member (Middle Proterozoic)**—Gray to greenish gray to white siltite and dark gray argillite, with scattered white quartzite beds at base and top. Overall, bedding uneven, with slight loading or channeling at bed or couplet bases common. Some siltite as 10 cm thick beds have no discernable internal structure. Other siltite as bases of microlaminae to couplets with white silt grading upward to dark gray silt. The gray tops do not form parting surfaces and appear to have little more argillite than the white bases. Dark specs within siltite appear to be biotite low in unit, but magnetite toward the top as the siltite beds become greener. White quartzite beds 10-50 cm (rarely to m) present at the base of the unit are scattered throughout the lower part. Quartzite very fine grained and characterized by dark mm-thick horizontal planar laminations, as well as common ripple and larger low angle cross-laminations, small "dish" structures, and scattered load structures to 15 cm in depth. Manganese carbonate "pods" occur as round to oblong, brown weathering spots or cavities 5-15 cm in diameter. Sedimentary structures such as incipient and polygonal cracks, ripples, and mudchips are common on argillitic surfaces of bedding plane partings throughout the unit. Upper contact placed above uppermost recognized dark gray argillite tops, where lighter greenish gray argillites of *Yb* dominate. Inclusion of some quartzite at top where dark argillite persists but is a minor component probably accounts for higher placement of contact and greater thickness (450-500 m, -1640 feet) than in previous mapping (240-300 m, 800-1000 feet; Harrison and Jobin, 1963). Greater thickness to north (640 m, 2100 feet; Burmester, 1986) is not attributable to different contact criteria. Mapped here as "transition zone" into overlying Burke Formation whereas elsewhere included in Burke (e.g., Cressman, 1985).

Yph **Prichard Formation, member h (Middle Proterozoic)**—Laminated gray siltite and black argillite couplets to microlaminated black and white argillite. Laminae and microlaminae characteristically very even and continuous. Parting commonly mm to cm. Weathers with a distinct rusty veneer, and is a resistant cliff-forming unit in the map area. Uppermost contact placed at the lowest occurrence of white quartzites and wavy siltite and argillite couplets of overlying *Ypt*. Thickness of about 580-700 m (1900-2300 feet) (610-670 m; 2000-2200 feet; Harrison and Jobin, 1963) is in between thickness of unit to the southeast (1450-1770 m, 4760-5810 feet; Cressman, 1985) and north (370 m, 1200 feet; Burmester, 1986). This is nicknamed the "lined unit" of the Prichard Formation.

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 placed below thick interval of flat laminated dark gray siltite and argillite. Thickness of 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 couplets, laminated light gray and dark gray siltite, and minor lighter quartzite. Lamination and parting typically thicker than in *Yph*. 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 910 m to the north (3000 feet; Burmester, 1986), unit is repeated by mapped and unmapped, down to the west normal faults and perhaps northwest vergent thrust faults. It seems plausible that the Lightning Creek stock intruded one or more such faults. Upper contact placed at base of concentration of quartzite.

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. The major structures are described below.

EARLY THRUST FAULTS

We found bedding plane parallel shears on Antelope Mountain just west of the map area, 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 with more displacement that are not well exposed but duplicate some parts of the section, specifically *Ypf* across and west of Lightning Creek. Small folds and disparate attitudes around the Lightning Creek stock have been attributed to its intrusion (Harrison and Jobin, 1963; Fillipone and Yin, 1994) but it is conceivable that an early thrust fault along Lightning Creek accounts for some deformation and accommodated the stock. If true, lack of fabric in the stock indicates that thrusting had ceased there by 74 Ma.

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), but it appears to have posed no barrier to the *Ydb* sill near the bottom of *Yb*, which is found with similar thickness and at nearly the same stratigraphic level north of the fault on this map and south of it on the Hope quadrangle to the west. 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.

SURARLOAF SYNCLINE

Sugarloaf Mountain is mostly carbonate-bearing rocks of the Shepard Formation. Outcrops are sparse, and attitudes are highly varied. Most road cuts are in colluvium of angular clasts of Shepard lithologies. Rare exposures of fold hinges show that the hinge zones are highly fractured. Only planar beds close to exposed hinges can be interpreted as limbs of those folds. Disparate attitudes of hinges and limbs suggest that they are separated by faults. The apparent anomalous thickness for the Shepard Formation at Sugarloaf Mountain is attributable to complex folding and faulting, at least partly at shallow levels during Eocene extension.

SUGARLOAF FAULT

There must be a fault southwest of Sugarloaf Mountain to drop Libby Formation rocks down on the southwest relative to the Shepard Formation. Harrison and Jobin (1963) placed it close to the south end of Sugarloaf because they assigned rocks there to the Libby Formation. However, we were unable to find chert-like clasts or beds in those rocks, so interpreted them as argillite of Howe Mountain. Thus, we placed the fault farther southwest.

DIKE FAULT

Harrison and Jobin (1963) projected the "Dike fault" through an exposure of *Kpd* under Quaternary cover. Lack of fabric in this body suggests that it is postkinematic relative to any fault it might have intruded, but abundant thin (mm-thick) vuggy quartz fractures attest to brittle deformation later, probably in the Eocene.

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