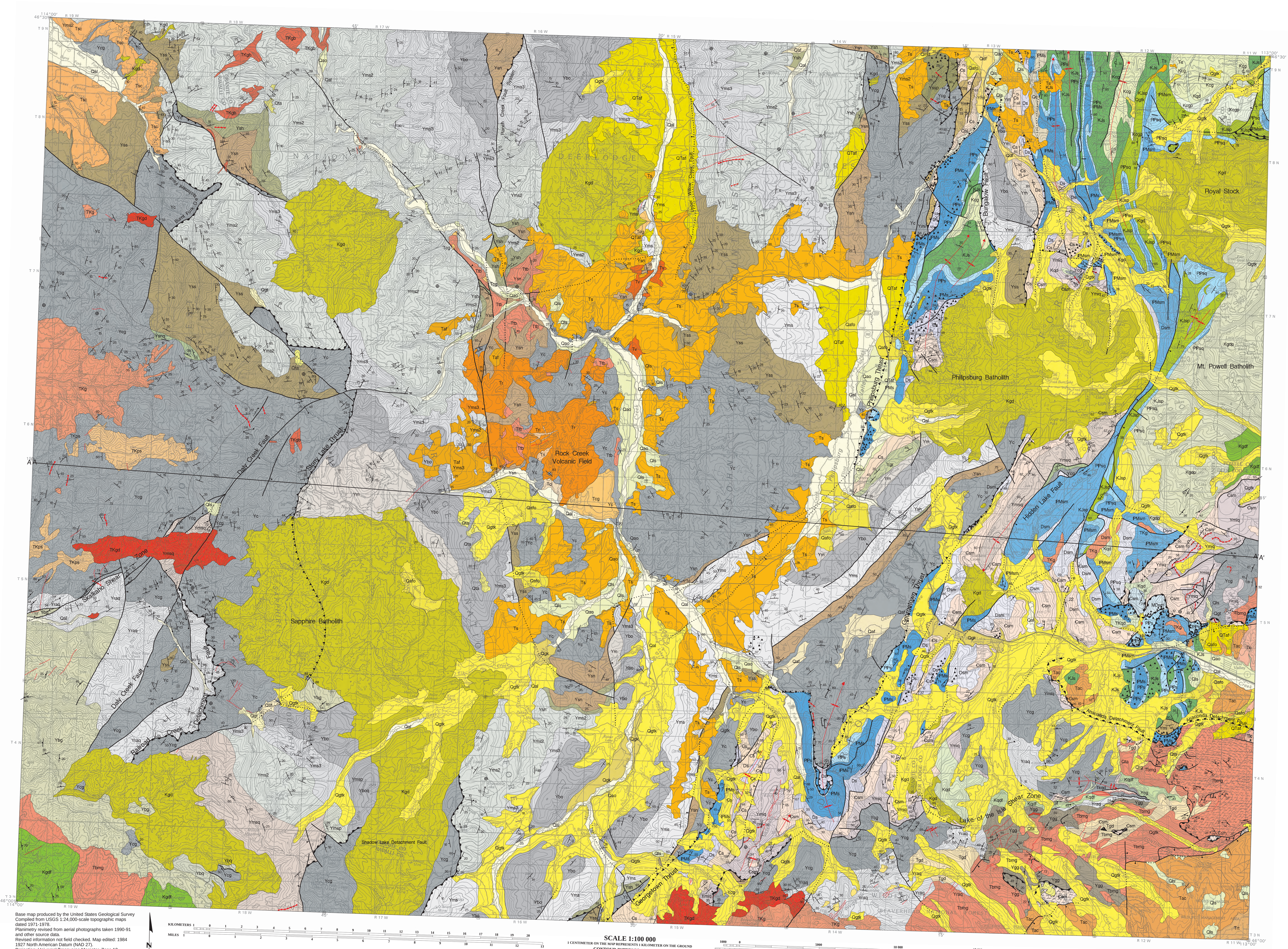
MONTANA BUREAU OF MINES AND GEOLOGY
A Department of Montana Tech of The University of Montana

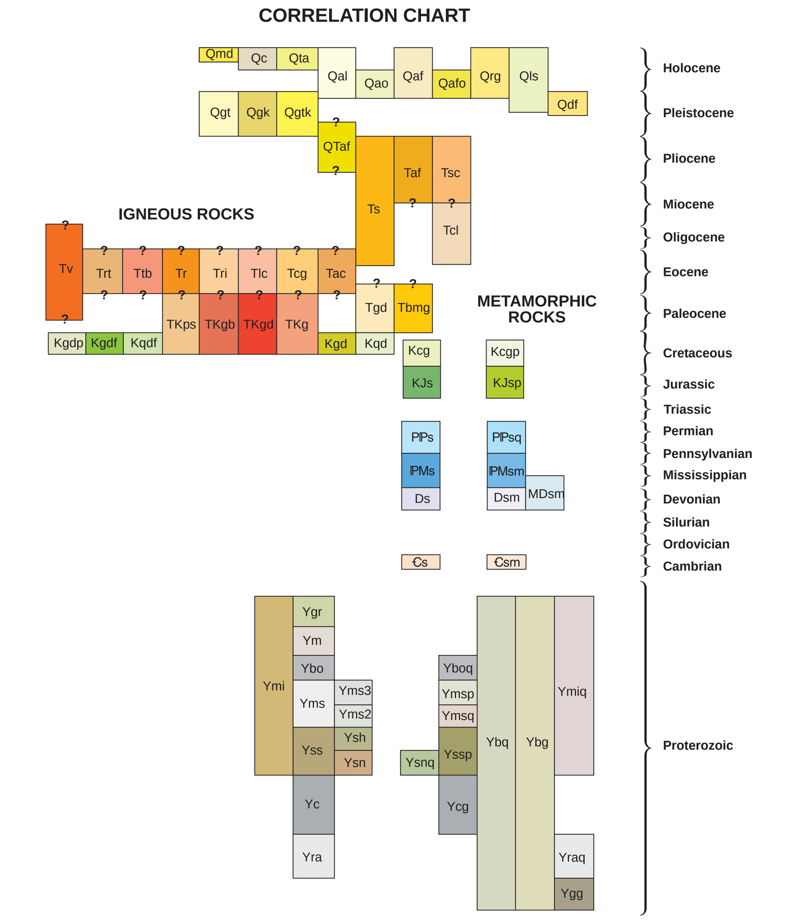


Base map produced by the United States Geological Survey
Compiled from USGS 1:24,000-scale topographic maps dated 1971-1978.
Planimetry revised from aerial photographs taken 1990-91 and other source data.
Revised information not field checked. Map edited: 1984
1927 North American Datum (NAD 27).
Projection: Universal Transverse Mercator, Zone 12
UTM grid declination 1°42' West
1980 Magnetic North Declination 16.5° East
National Geodetic Vertical Datum of 1929

MAP SYMBOLS

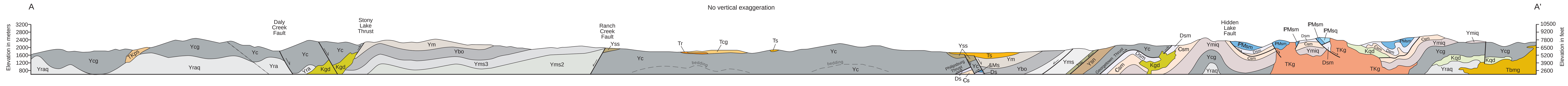
- Contact
- Fault: unknown series of movement, dotted where concealed
- Normal fault: dotted where concealed; bar and ball on downthrown side
- Reverse or thrust fault: teeth on upthrown block
- Low angle normal fault (detachment fault) hatches on hanging wall, dashed where approximately located; dotted where concealed
- Anticline: showing trace of axial plane and plunge direction where known
- Syncline: showing trace of axial plane and plunge direction where known
- Overturned anticline: showing trace of axial plane and direction of dip bedding
- Small scale fold axis
- Strike and dip of bedding
- Strike and dip of overturned bedding
- Strike and dip of bedding where stratigraphic "up" direction was confirmed using primary sedimentary structures
- Strike and dip of overturned bedding where stratigraphic "up" direction was confirmed using primary sedimentary structures
- Horizontal bedding
- Foliation
- Mylonitic foliation, with plunge and bearing of mineral lineation
- Cleavage
- Gabbroic or dioritic sills and dikes
- Granitic or granodioritic sills and dikes
- Areas of significant tectonic breccia
- Areas of mylonitic fabric along the east side of the Anaconda core complex

CORRELATION CHART



Cross Section A-A'

No vertical exaggeration



Datum = mean sea level
Surficial deposits not shown

Montana Bureau of Mines and Geology
Open File 483 Plate 1

Geologic Map of the Philipsburg 30' x 60' Quadrangle, Western Montana

Jeffrey D. Lonn[1], Catherine McDonald[1], Reed S. Lewis[2], Thomas J. Kalakay[3], J. Michael O'Neill[4], Richard B. Berg[1], and Phyllis Hargrave[1]

2003 (Revised 2010)

[1] Montana Bureau of Mines and Geology; [2] Idaho Geological Survey; [3] Rocky Mountain College; [4] U.S. Geological Survey

Quad index

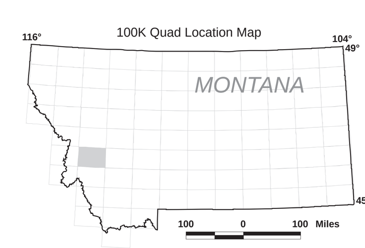
MISSOULA WEST	MISSOULA EAST	ELLISTON
HAMILTON	PHILIPSBURG	BUTTE NORTH
NEZ PERCE PASS	WISDOM	BUTTE SOUTH

Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S.Geological Survey under Contract Number 02 HQAG0038.

GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.

Revised	Date
Map and text by Jeffrey D. Lonn	6/09
Map and text by Jeffrey D. Lonn	7/10

100K Quad Location Map



Maps may be obtained from
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street, Butte, Montana 59701-8997
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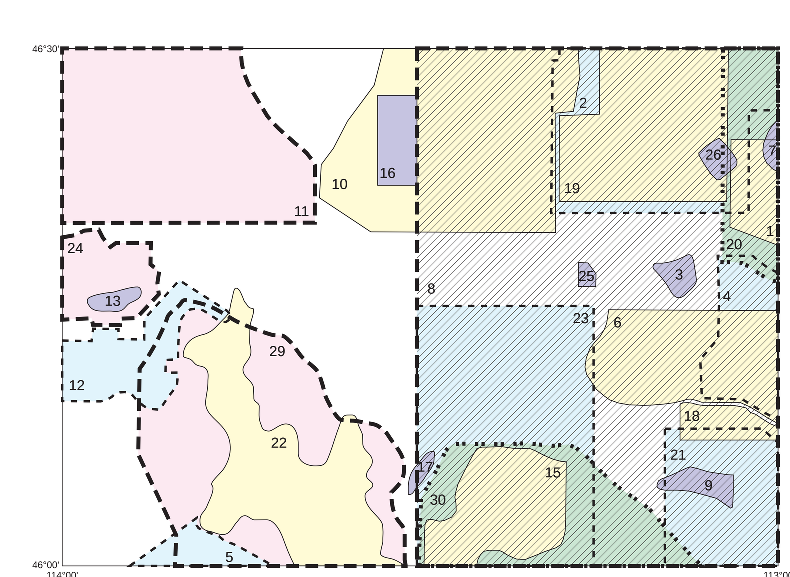
http://www.mbmg.mtech.edu



SOURCES 0F PREVIOUS GEOLOGIC MAPPING

1. Allen, 1961
2. Bakken, 1984
3. Buckley, 1990
4. Csejtey, 1962
5. Desmarais, 1983
6. Earll, 1972
7. Elliott and others, 1984
8. Emmons and Calkins, 1913
9. Heise, 1983
10. Hughes, 1970
11. Langton, 1935
12. LaTour, 1974
13. Lelek, 1979
14. Lewis, 1998a
15. Lidke and Wallace, 1992
16. Loen and others, 1989
17. Lofholm, 1985
18. Mahorney, 1956
19. McGill, 1961
20. Mutch, 1961
21. Noel, 1956
22. Pederson, 1976
23. Poulter, 1956
24. Presley, 1971
25. Prinz, 1967
26. Stuart, 1966
27. Wallace, 1987
28. Wallace and others,1986
29. Wallace and others, 1989
30. Wallace and others,1992

These sources cover the whole 100,000 scale quadrangle

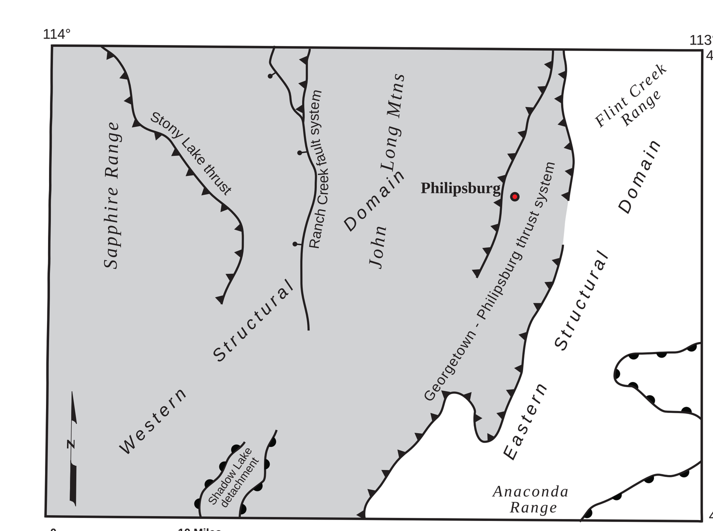


Figure 1. Major tectonic features, structural domains, and mountain ranges of the Philipsburg 30' x 60' quadrangle.

MAP UNIT DESCRIPTIONS

Qmd MINE WASTE (HOLOCENE)
Piles of poorly sorted cobbles, boulders, and sand resulting from placer mining operations. Thickness 1.5-7.5 m (5-25 ft).

Qc COLLUVIUM (HOLOCENE)
Thin, unconsolidated slope wash, talus, and rock fall deposits. Thickness 1.5-7.5 m (5-25 ft).

Qta TALUS DEPOSITS (HOLOCENE AND PLEISTOCENE)
Accumulations of angular boulders below cliffs. Thickness 1.5-15.0 m (5-25 ft).

Qal ALLUVIUM OF MODERN CHANNELS AND FLOODPLAINS (HOLOCENE)
Mostly well-rounded, well-sorted boulders, cobbles, gravel, sand, and silt deposited in modern stream channels and floodplains. Includes both fine-grained overbank deposits and coarse-grained channel deposits. In some areas, older alluvium (Qao) is not divided from Qal.

Qao OLDER ALLUVIUM (EARLY HOLOCENE AND LATE PLEISTOCENE?)
Mostly well-rounded, well-sorted boulders, cobbles, sand, and silt deposited by streamflow processes. Surfaces of these deposits now stand 1.5-12.1 m (5-40 ft) above the modern floodplain. Includes terrace deposits along streams and glacial outwash deposited by braided streams.

Qaf ALLUVIAL FAN DEPOSITS (HOLOCENE AND PLEISTOCENE)
Poorly to well-sorted, rounded to sub-angular boulders, cobbles, sand, silt, and clay. Surfaces of these deposits have a distinct fan shape. Deposited by both stream flow and debris flow processes in alluvial fan environments. In some areas, older alluvial fan deposits (Qafo) are not divided from Qaf.

Qafo OLDER ALLUVIAL FAN DEPOSITS (EARLY HOLOCENE AND LATE PLEISTOCENE?)
Fans whose surfaces are now perched 1.5-12.1 m (5-40 ft) above the modern landforms.

Qrg ROCK GLACIER DEPOSITS (HOLOCENE)
Lobate accumulations of angular boulders emplaced by flow of an ice core. Active and inactive rock glaciers are not divided.

Qls LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)
Unsorted and unstratified mixtures of mud and boulders transported by mass movement down steep slopes. Characterized by irregular topography.

Qdf DEBRIS FLOW DEPOSITS (PLEISTOCENE)
Poorly sorted, sub-angular bouldery deposits of huge boulders, cobbles, sand, silt and clay deposited by catastrophic debris flows.

Qgtk GLACIAL TILL AND KAME DEPOSITS, UNDIVIDED (PLEISTOCENE)

Qgt GLACIAL TILL (PLEISTOCENE)
Unsorted, mostly unstratified, clay, silt, sand, and gravel with subrounded boulders as much as 3 m (10 ft) in diameter. Till is often characterized by large, subrounded, exotic boulders that have been transported some distance, and by hummocky topography. Poor drainage, with swampy areas and numerous springs, and subangular clasts distinguish it in the field from kame deposits (Qgk).

Qgk GLACIAL KAME DEPOSITS (PLEISTOCENE)
Moderately to well-sorted, sub-rounded to well-rounded, well-stratified sand, pebbles, and boulders deposited by streams flowing within, on, and marginal to glaciers. Topographic surfaces tend to be hummocky and contain ridges and kettles. Distinguished in the field from glacial till (Qgt) by the roundness of the clasts and by the deposits' well-drained nature. Include some poorly sorted fan deposits developed on or marginal to the glaciers.

QTaf ALLUVIAL FAN DEPOSITS (EARLY PLEISTOCENE AND LATE TERTIARY)
Poorly to well-sorted, rounded to sub-angular boulders, cobbles, sand, silt, and clay. Surfaces of these deposits have a distinct fan shape and now stand more than 15 m (50 ft) above modern deposits.

Ts SEDIMENTARY ROCKS, UNDIVIDED (TERTIARY)
Include both coarse- and fine-grained rocks.

Taf ALLUVIAL FAN DEPOSITS (TERTIARY)
Poorly to well-sorted, rounded to sub-angular boulders, cobbles, sand, silt, and clay. Surfaces of these deposits now stand more than 15 m (50 ft) above modern deposits. Unlike younger alluvial fan deposits (QTaf), these are often unrelated to modern drainage patterns.

Tsc SIXMILE CREEK FORMATION (PLIOCENE AND MIOCENE?)
Mostly conglomerate with some sandstone and siltstone. Commonly caps the remnant Tertiary surfaces.

Tcl CLAY AND SILT (MIOCENE AND OLIGOCENE?)
White to light-gray clay and silt deposited in fluvial and lacustrine environments, and probably correlative with the Renova Formation.

Tac ANACONDA BEDS, INFORMAL (EOCENE?)
Unstratified deposits of angular, poorly sorted boulders and cobbles of unmetamorphosed sedimentary rocks deposited in debris flow and mass wasting environments, interbedded with and grading to moderately sorted, sub-angular to rounded cobbles, pebbles, and sand deposited in fluvial environments. Emmons and Calkins (1913) first described these rocks in the Barker Creek area southeast of Silver Lake and called them "earlier Tertiary gravels". Csejtey (1962) described similar rocks near Anaconda and named them the Anaconda beds. They have been interpreted as deposits formed during the unroofing of the Anaconda core complex in basins developed along the detachment zone (O'Neill, 2005).

Tcg CONGLOMERATE (EOCENE?)
Clast-supported, sub-angular to rounded, moderately sorted boulders, cobbles, and pebbles of Belt Supergroup rocks. Contains rare volcanic clasts. Found in the area of the Rock Creek volcanic field.

Tv VOLCANIC ROCKS, UNDIVIDED (TERTIARY)
Volcanic and volcaniclastic rocks. Include minor hypabyssal intrusive bodies.

Ttb TUFF BRECCIA (EOCENE?)
Poorly stratified, poorly sorted, mostly clast-supported, angular boulder- to cobble-sized lithic fragments in an ash matrix. Clasts are predominantly local Belt Supergroup sedimentary rocks, but locally include abundant volcanic rocks. Matrix material is usually sparse, although in some areas ash-flow tuff predominates with few lithic fragments. Found in the area of the Rock Creek volcanic field.

Tr RHYOLITE (EOCENE?)
Rhyolite flows and tuff that contain abundant biotite phenocrysts and sparse potassium feldspar and quartz phenocrysts. Mapped in the Rock Creek volcanic field.

Tri INTRUSIVE RHYOLITE (EOCENE?)
Dikes containing euhedral potassium feldspar phenocrysts as much as 15 mm (0.5 in) long. Also contains sparse plagioclase, biotite, and quartz phenocrysts.

Tlc LOWLAND CREEK VOLCANICS (EOCENE)
Rhyolite and dacite flows, tuffs, and volcaniclastic rocks.

Trt RHYOLITE TUFF (EOCENE)
Mapped within the Lowland Creek volcanic field.

Tbmg BIOTITE-MUSCOVITE GRANITE (EOCENE AND PALEOCENE)
Equigranular and porphyritic biotite-muscovite granite. Mylonitic foliation is present within and adjacent to the Anaconda detachment fault.

Tgd GRANODIORITIC ROCKS (EOCENE AND PALEOCENE)
Quartz monzodiorite and granodiorite.

TKg GRANITIC ROCKS (EARLY TERTIARY AND LATE CRETACEOUS)
Non-foliated biotite-muscovite monzogranite, leucomonzogranite, and granodiorite.

TKgd GRANODIORITIC ROCKS (EARLY TERTIARY AND LATE CRETACEOUS)
Non-foliated biotite granodiorite, hornblende-biotite granodiorite, tonalite, and quartz diorite.

TKgb GABBROIC ROCKS (EARLY TERTIARY AND LATE CRETACEOUS)
Gabbro, microgabbro, diorite, and lamprophyre.

TKps PYROXENITE AND SYENITE (EARLY TERTIARY OR LATE CRETACEOUS)
Pyroxenite and syenite found near the western boundary of the map area.

Kqd QUARTZ DIORITE (LATE CRETACEOUS)
Hornblende-biotite quartz diorite, diorite, and granodiorite.

Kgd GRANODIORITIC ROCKS (LATE CRETACEOUS)
Biotite-hornblende granodiorite, biotite granodiorite, and tonalite.

Kgdp PORPHYRITIC GRANODIORTE (LATE CRETACEOUS).
Porphyritic, muscovite-bearing granodiorite of the Mount Powell Batholith.

Kgdf FOLIATED GRANODIORITE (LATE CRETACEOUS)
Moderately to strongly foliated biotite-hornblende granodiorite.

Kqdf FOLIATED QUARTZ DIORITE (LATE CRETACEOUS)
Weakly to stongly foliated quartz diorite of the eastern Anaconda Range.

Kcg COLORADO GROUP (EARLY TO LATE CRETACEOUS)
The upper Colorado Group consists of approximately 300 m (1,000 ft) of tan to brown lithic sandstone, gray to gray-green siltstone, minor shale, and local conglomerate. Sandstones often contain dark chert grains or volcanic fragments. The lower Colorado Group includes dark gray to black fissile shale underlain by tan to gray siltstone, fine-grained sandstone, and dark gray to black limestone. This lower part is more calcareous, and limestone is more abundant near the gradational contact with the underlying Kootenai Formation. The thickness of the Colorado Group is about 498 m (1,635 ft) (McGill, 1961).

Kcgp PHYLLITE OF THE METAMORPHOSED COLORADO GROUP (EARLY TO LATE CRETACEOUS)
Phyllite, quartzite, and minor marble that are the metamorphic equivalent of the Colorado Group.

KJs SEDIMENTARY ROCKS OF THE ELLIS AND KOOTENAI FORMATIONS, UNDIVIDED (JURASSIC AND CRETACEOUS)
The upper part of the non-marine Kootenai Formation includes as much as 40 m (130 ft) of gray, gastropod-bearing limestone at the top underlain by gray to reddish calcareous shale, siltstone, and sandstone. The middle part consists of about 275 m (900 ft) of maroon, green, and gray mudstone and siltstone with minor calcareous sandstone. The lower Kootenai, approximately 91 m (300 ft) thick, includes an interval of finely crystalline gray limestone with varicolored siltstone and mudstone mostly underlain by gray to red-brown feldspathic sandstone and siltstone with widespread gray-chert conglomerate. The upper Ellis Formation is calcareous gray sandstone, siltstone, and shale with locally thin, calcareous conglomeratic beds containing abundant pebbles and sand-sized grains of black chert. The lower Ellis includes non-calcareous black fissile shales, dark gray to black calcareous shales and siltstones, and thin limestone fossil-hash beds. The Ellis Formation is approximately 85 m (280 ft) thick.

KJsp PHYLLITE AND QUARTZITE OF THE METAMORPHOSED KOOTENAI AND ELLIS FORMATIONS (JURASSIC AND CRETACEOUS)
Phyllite, quartzite, marble, and schist that are the metamorphic equivalents of the Kootenai and Ellis Formations.

PPs SEDIMENTARY ROCKS OF THE SHEDHORN, PHOSPHORIA, PARK CITY AND QUADRANT FORMATIONS, UNDIVIDED (PERMIAN AND PENNSYLVANIAN)
The Shedhorn Formation is tan to white orthoquartzite, locally cross-bedded and pitted, approximately 9 m (30 ft) thick. The Phosphoria Formation is bedded, dark gray to red chert, chert conglomerate, minor calcareous siltstone, gray to black phosphatic shale, phosphorite, and argillaceous carbonate that is commonly oolitic. Approximately 20 m (65 ft) thick. The Park City Formation is predominantly calcareous sandstone, siltstone, and nodular cherty limestone. Thickness is about 37 m (120 ft). The Quadrant Formation is a cliff-forming, massive, white to light gray quartzitic sandstone, red-brown to black on weathered surfaces. Approximately 30 m (100 ft) thick.

PPsq QUARTZITE OF THE METAMORPHOSED SHEDHORN, PHOSPHORIA, PARK CITY AND QUADRANT FORMATIONS (PERMIAN AND PENNSYLVANIAN)
Mostly quartzite, but also includes minor phyllite and marble. Metamorphic equivalent of the Shedhorn, Phosphoria, Park City, and Quadrant Formations.

PMs SEDIMENTARY ROCKS OF THE SNOWCREST RANGE GROUP, AMSDEN FORMATION, AND MADISON GROUP, UNDIVIDED (PENNSYLVANIAN AND MISSISSIPPIAN)
The Snowcrest Range Group (Lidke and Wallace, 1992) and equivalent Amsden Formation (Emmons and Calkins, 1913; Poulter, 1956; McGill, 1961) consist mainly of maroon, thin-bedded dolomite overlain by maroon dolomitic shale with minor light gray limestone and dolomite. Recessive weathering; generally mapped by presence of red soil zone. Approximately 91 m (300 ft) thick. The Madison Group consists of massive-weathering, thick-bedded, white to bluish-gray, fossiliferous, cherty limestone underlain by dark gray, flaggy limestone with interbedded, black calcareous shale. Approximate thickness as much as 1,022 m (2,300 ft) (McGill, 1961).

PMsm MARBLE OF THE METAMORPHOSED SNOWCREST RANGE GROUP, AMSDEN FORMATION, AND MADISON GROUP (PENNSYLVANNIAN AND MISSISSIPPIAN)
Mostly marble, but also includes some minor phyllite. Metamorphic equivalent of the Snowcrest Range Group, Amsden Formation, and Madison Group. This unit is often tectonically thinned. See geologic discussion for more detail.

MDsm MARBLE OF METAMORPHOSED SEDIMENTARY ROCKS, UNDIVIDED (MISSISSIPPIAN AND DEVONIAN)
Metamorphic equivalents of Madison Group, Three Forks Formation, Jefferson Dolomite, and Maywood Formation.

Ds SEDIMENTARY ROCKS OF JEFFERSON AND MAYWOOD FORMATIONS, UNDIVIDED (UPPER DEVONIAN)
The Jefferson Formation, approximately 260 m (850 ft) thick, consists of thick-bedded, dark gray to black dolomite with minor interbedded light gray limestone. Limestone beds are more common in upper part and are often brecciated. Alternating light and dark beds and a petroliferous odor are characteristic. The Maywood Formation consists of thin bedded, gray, reddish gray, and yellow dolomitic shale and siltstone, silty dolomite, and sparse gray limestone. Upper part contains minor quartzite and dark dolomite beds similar to overlying Jefferson Formation. Basal part contains beds of dolomitic and calcareous sandstone and siltstone. Thickness 84-106m (275-350 ft).

Dsm MARBLE OF THE METAMORPHOSED JEFFERSON AND MAYWOOD FORMATIONS (UPPER DEVONIAN)
Includes marble that is the metamorphic equivalent of the Jefferson Formation and quartzite and phyllite equivalent to the Maywood Formation. This unit is often tectonically thinned. See geologic discussion for more detail.

Cs SEDIMENTARY ROCKS OF THE RED LION, HASMARK, SILVER HILL AND FLATHEAD FORMATIONS, UNDIVIDED (CAMBRIAN)
The Red Lion Formation is predominately light gray to blue gray limestone with yellow- to red-weathering, wavy, dolomitic and siliceous laminae. Laminae are less common near top of formation. Basal part contains black calcareous shale with minor sandstone and limestone. The thickness is approximately 100 m (330 ft). The Hasmark Formation, approximately 320 m (1,050 ft) thick,is a uniform, light to blue gray dolomite that is separated into an upper and lower part by a recessive shale interval. The lower dolomite is generally darker in color than the upper part and commonly contains oolitic structures and mottled weathered surfaces. The shale interval is as much as 46 m (150 ft) thick and varies from dark brown to reddish purple calcareous shale to reddish limestone and shale. The Silver Hill Formation, approximately 185 m (600 ft) thick, includes calcareous brown, white, and green shale interbedded with laminated limestone underlain by moderately thick-bedded, laminated, light-gray limestone. Laminae are generally siliceous and stand in relief on weathered surfaces. The basal unit consists of olive green, fissile, generally non-calcareous shale. The Flathead Formation is a white to reddish weathering, fine to coarse grained, orthoquartzite that is locally conglomeratic. Beds are thinner and finer grained near the contact with the overlying Silver Hill Formation. Relatively common features include crossbedding, ripple lamination, and locally hematitic cement. Thickness 22-61 m (50-200 ft).

Csm MARBLE AND QUARTZITE OF THE METAMORPHOSED RED LION, HASMARK, SILVER HILL AND FLATHEAD FORMATIONS (CAMBRIAN)
Includes marble, quartzite, gneiss, schist, and phyllite that are the metamorphic equivalents of these formations. This unit is often tectonically thinned. See geologic discussion for more detail.

Ymi MISSOULA GROUP, UNDIVIDED (MIDDLE PROTEROZOIC)
Includes, in descending order, the Garnet Range, McNamara, Bonner, Mount Shields, Shepard, and Snowslip Formations. Total thickness as much as 3,261 m (10,700 ft).

Ymiq QUARTZITE AND PHYLLITE OF THE METAMORPHOSED MISSOULA GROUP (MIDDLE PROTEROZOIC)
Quartzite, phyllite, schist, calc-silicate rocks, and gneiss that are metamorphic equivalents of the Missoula Group. The Bonner, McNamara, and Garnet Range Formations have been eroded off. In addition, this unit is often tectonically thinned, and varies from 62 to 677 m (200 to 2,200 ft) in thickness. See the geologic discussion for more detail.

Ygr GARNET RANGE FORMATION (MESOPROTEROZOIC)
Greenish-gray, micaceous, tabular and lensoidal, hummocky cross-stratified, fine-grained quartzite with argillite interbeds. In some areas, purple and white, crossbedded quartzite of the Mesoproterozoic Pilcher Formation overlies the Garnet Range (Winston and Wallace, 1983), and is included in the Ygr designation. Pre-middle Cambrian erosion removed the Garnet Range from much of the map area, but it has a thickness of about 305 m (1,000 ft) on Flint Creek Hill near Georgetown Lake.

Ym MCNAMARA FORMATION (MESOPROTEROZOIC)
Beds of flat-laminated and trough crossbedded, fine- to medium-grained quartzite capped by thin argillite beds. Cherty rip-up clasts are common and diagnostic. Coarser in the map area than in its type locality near Missoula. From 0 to 457 m (1,500 ft) thick.

Ybo BONNER FORMATION (MESOPROTEROZOIC)
Pink, medium-grained, feldspathic, crossbedded quartzite. In the southeastern part of the map area, pebbles are abundant. Lewis (1998b) found 15-25% potassium feldspar but only a trace of plagioclase in the Bonner Formation. Approximately 518 m (1,700 ft) thick.

Yboq QUARTZITE OF THE METAMORPHOSED BONNER FORMATION (MESOPROTEROZOIC)
Highly recrystallized quartzite with minor phyllite and schist. Metamorphic equivalent of the Bonner Formation.

Yms MOUNT SHIELDS FORMATION (MESOPROTEROZOIC)
Usually divided into 3 informal members that are not distinguishable everywhere. Total thickness is approximately 1,219 m (4,000 ft).

Yms3 MOUNT SHIELDS FORMATION, MEMBER 3, INFORMAL (MESOPROTEROZOIC)
Mostly red siltite to argillite couples and couplets with abundant mudcracks, mud chips, and salt casts.

Ymsp PHYLLITE OF THE METAMORPHOSED MOUNT SHIELDS FORMATION, MEMBER 3 (MESOPROTEROZOIC)
Phyllite, quartzite, and minor schist that are the metamorphic equivalents of Mount Shields Member 3.

Yms2 MOUNT SHIELDS FORMATION, MEMBER 2, INFORMAL (MESOPROTEROZOIC)
Pink to gray, flat-laminated, fine- to-medium grained quartzite, with tan-weathering dolomitic blebs. Contains some crossbeds. In the Anaconda Range of the southernmost part of the map area, and in the Skalkaho region, the Mount Shields contains abundant pebbles and crossbeds, making it difficult to distinguish from the Bonner Formation. However, in contrast to the Bonner, Lewis (1998b) found subequal amounts of plagioclase and potassium feldspar and a total feldspar content of 25-35% in the Mount Shields.

Ymsq QUARTZITE OF THE METAMORPHOSED MOUNT SHIELDS FORMATION, MEMBER 2 (MESOPROTEROZOIC)
Metamorphic equivalent of the Mount Shields Member 2.

Yss SHEPARD AND SNOWSLIP FORMATIONS, UNDIVIDED (MESOPROTEROZOIC)
Total thickness as much as 1,067 m (3,500 ft).

Yssp PHYLLITE, QUARTZITE, AND CALC-SILICATE ROCKS OF THE METAMORPHOSED SHEPARD AND SNOWSLIP FORMATIONS (MIDDLE PROTEROZOIC)
Metamorphic equivalent of these formations.

Ysh SHEPARD FORMATION (MESOPROTEROZOIC)
Dark green siltite and light green argillite in microlaminae and couplets that are dolomitic and have a characteristic orange-brown weathering rind. Upper part is red, thinly bedded dolomitic quartzite and siltite. Poorly exposed but weathers into thin plates. Estimated to be 152 m (500 ft) thick.

Ysn SNOWSLIP FORMATION (MESOPROTEROZOIC)
Mostly red sand to clay couplets with abundant ripples and mud cracks. Green and red, dolomitic siltite-argillite laminae are common near the base. Increasing amounts of siltite and quartzite up section. Some fine- to medium-grained, feldspar-poor quartzite is present in beds less than one foot thick The upper portion is mostly flat-laminated, medium- to coarse-grained quartzite that is difficult to distinguish from the Mount Shields Formation. Mudcracks and mud chips are abundant throughout.. In the Anaconda Range are some thin lenticular beds of coarse-grained quartzite that contain granule-sized lithic fragments. Thickness as much as 914 m (3,000 ft).

Ysnq QUARTZITE OF THE METAMORPHOSED SNOWSLIP FORMATION (MESOPROTEROZOIC)
Highly recrystallized quartzite, phyllite, schist, and calc-silicate rocks that are the metamorphic equivalents of the Snowslip Formation.

Yc PIEGAN GROUP (MESOPROTEROZOIC)
Includes the Wallace and Helena Formations. The upper part, the Wallace Formation, is characterized by tan-weathering dolomitic siltite and quartzite capped by black argillite in pinch-and-swell couplets and couples. The quartzite and siltite commonly have scoured bases or bases with load casts. Sedimentary breccia, consisting mostly of white quartzite clasts in punky, orange-weathering silty dolomite, is common in the western part of the map area. The lower part, the Helena Formation, consists of cycles, from 1 to 9 m (3 to 30 ft) thick and usually incomplete, of a basal white quartzite or intraclast unit, overlain by even and lenticular couplets of green siltite and argillite without mud cracks, and capped by dolomitic beds. However, these cycles are difficult to recognize in the typical small outcrop. The unit is more easily recognized by wavy but parallel, silver-green couplets of darker green siltite and lighter green argillite, by white quartzite, by beds of tan- or brown-weathering dolomite 30-90 cm (1-3 ft) thick, and by weathered-out pods of carbonate in the green siltite. Molar-tooth structures and non-polygonal "crinkle" cracks are common throughout the section. Severe deformation within this unit makes thickness estimates problematic, but it is probably at least 1,846 m (6,000 ft) thick.

Ycg CALC-SILICATE GNEISS OF THE METAMORPHOSED PIEGAN GROUP (MESOPROTEROZOIC)
Greenish, diopside-rich, calc-silicate gneiss, fine-grained quartzite, marble, and minor schist. Metamorphic equivalent of the Piegan Group.

Yra RAVALLI GROUP (MESOPROTEROZOIC)
Mostly gray, flat-laminated, fine- to medium-grained quartzite in beds 0.15-1.5 m (0.5-5 ft) thick separated by thin argillite layers. Not significantly metamorphosed. Found in the Skalkaho area under a gently east-dipping fault; above the fault is Piegan Group. Contains sub-equal amounts of potassium and plagioclase feldspar similar to Mt. Shields member 2 (unit Yms2), but unlike nearby exposures of Mount Shields, it contains no pebbles. Soft sediment deformation is common. The unit is tentatively correlated with the Revett Formation of the Ravalli Group. Thickness is at least 914 m (3,000 ft).

Yraq QUARTZITE OF THE METAMORPHOSED RAVALLI GROUP (MESOPROTEROZOIC)
Gray, fine- to medium-grained quartzite in beds 0.15-1.5 m (0.5-5 ft) thick separated by thin phyllite or schist layers. Although original sedimentary structures are only partially preserved, the dominant sediment type appears to be flat-laminated sand, with crossbeds uncommon. Soft sediment deformation is common. The unit is tentatively correlated with the Revett Formation. Wallace and others (1989, 1992) mapped this unit as Mount Shields Formation, but along lower Skalkaho Creek and near Storm Lake it can be demonstrated to be in stratigraphic contact with the overlying Piegan Group. Unit includes a thin zone of locally kyanite-bearing pelitic gneiss that separates quartzite from the overlying Piegan Group and may be equivalent to the Saint Regis Formation of the Ravalli Group. Contains 14-21% K-spar and only 0-10% plagioclase. However, metamorphism may have affected these concentrations in unknown ways.

Ygg PELITIC GNEISS AND SCHIST OF THE METAMORPHOSED GREYSON FORMATION (MESOPROTEROZOIC)
Mostly reddish-brown-weathering biotite-muscovite schist containing variable amounts of quartz, sillimanite, cordierite, feldspar, garnet, and andalusite. Kyanite and kyanite pseudomorphs are rare constituents.

Ybq BIOTITE QUARTZITE OF THE METAMORPHOSED BELT SUPERGROUP (MESOPROTEROZOIC)
Highly recrystallized, fine- to medium-grained quartzite in layers 10-30 cm (4-12 in) thick separated by biotite-rich bands. Although these rocks are almost certainly metamorphosed Belt quartzites, we were unable to identify their equivalent formations.

Ybg GNEISS, QUARTZITE, CALC-SILICATE ROCKS, SCHIST, AND PHYLLITE OF THE METAMORPHOSED BELT SUPERGROUP (MESOPROTEROZOIC)
Highly recrystallized gneissic and schistose rocks to which we were unable to assign formation or group equivalents, but that probably belong to the Belt Supergroup.

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Montana Bureau of Mines and Geology
Open File 483, Plate 2

Geologic Map of the Philipsburg 30' x 60' Quadrangle, Western Montana

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2003 (Revised 2010)

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GEOLOGIC SUMMARY

Introduction

Montana Bureau of Mines and Geology's new Geologic Map of the Philipsburg 30' x 60' Quadrangle represents a revised version of the Preliminary Geologic Map of the Philipsburg Quadrangle (Lonn and others, 2003) based on new field work by Lonn and Lewis from 2003 to 2008. This new field work addressed structural and stratigraphic problems revealed by, but not resolved on, the previous map.

Structural Geology

The Philipsburg quadrangle can be divided into two major structural domains separated by the north-northeast-striking Georgetown-Philipsburg thrust system (fig. 1). The eastern structural domain, comprising the Flint Creek and northeastern Anaconda Ranges, is characterized by upper greenschist to upper amphibolite facies metamorphism, tight folds, closely spaced faults, and a complex structural history. The western domain, previously termed the Sapphire tectonic block (Hyndman and others, 1975) or Skalkaho slab (Doughty and Sheriff, 1992), is an allochthon composed mostly of low-grade metasedimentary rocks deformed into upright, open folds and cut by numerous reverse and normal faults. Both domains are extensively intruded by late Cretaceous to early Tertiary granitic and dioritic plutons.

Eastern Structural Domain

Structural geology is extremely complex within the eastern domain. Major east-directed thrust faults, represented by the Georgetown-Philipsburg thrust system, presumably buried the rocks of the eastern domain to mid-crustal depths in late Cretaceous time. An increase in metamorphic grade from west to east probably reflects greater uplift in the east. The southeastern-most part of the Anaconda Range contains relict kyanite and kyanite psuedomorphs (Kalakay and others, 2003; Grice, 2006) indicative of high-pressure metamorphism, overprinted by a high-temperature, lower pressure metamorphic event at about 80-75 Ma (Grice and others, 2004, 2005; Grice, 2006; Haney, 2008).

In the Flint Creek and Anaconda Ranges, the Mesoproterozoic through Mesozoic metasedimentary sequence appears to be tectonically attenuated by an array of bedding-parallel fabrics and structures that include concordant mylonitic shear zones that cut out stratigraphic section, zones of vertical shortening that flatten the units through pure shear and plastic flow, and brittle bedding-parallel faults that place younger units over older units (Lonn and McDonald, 2004a,b; Lonn and Lewis, 2009). Parallel solid-state fabrics are present in the oldest (> 75 Ma) late Cretaceous plutons (units Kgdf,Kqdf) intruding the metasediments (Hawley, 1974; Desmarais, 1983; Grice and others, 2005; Grice, 2006). The strain fabrics apparently formed during the 75-80 Ma high temperature metamorphic event (Grice and others, 2004, 2005; Grice, 2006), and they have been deformed with the beds into tight, NNE-trending, west-verging, asymmetric to overturned folds whose east-dipping axial planes appear to become more gently inclined with increasing structural depth. Undeformed late Cretaceous to early Tertiary plutons intrude the metasediments. Most plutons are sheet-like and roughly concordant to bedding, and their intrusion may have been synchronous with the folding.

The eastern flanks of the Anaconda and Flint Creek Ranges are overprinted by structures and fabrics associated with the Eocene Anaconda metamorphic core complex (O'Neill and others, 2002, 2004). The confusing geology in the southeastern corner of the Philipsburg quadrangle typifies map patterns in this extensional terrane. Here, chaotic, brecciated sedimentary rocks of the upper plate are separated from lower plate metamorphic and plutonic rocks by brittle detachment faults and a greenschist-facies mylonitic shear zone. The sinuous and discontinuous Anaconda mylonite, gently folded and broken by faults, extends for more than 100 km (62 miles) along strike. It dips gently east, has a top-to-the-east shear sense, and was active from at least 53 to 47 Ma (Grice and others, 2005; Grice, 2006). Mineral lineations consistently plunge gently ESE (102°-108°), bearings almost identical to those associated with the coeval (Foster and others, 2007) Bitterroot metamorphic core complex 100 km (62 miles) to the west and outside the quadrangle.

The Georgetown-Philipsburg Thrust

The Georgetown-Philipsburg thrust system divides the western and eastern domains. It is a complex imbricate fault system that places Mesoproterozoic Piegan Group of the Belt Supergroup over upper Paleozoic and Mesozoic sediments for a total stratigraphic separation of 7,400 m (24,000 ft). Regional cross sections that restore the slight angular unconformity at the Belt-Cambrian contact suggest about 35 km (22 miles) of horizontal displacement. The Georgetown fault is folded, perhaps by the same folds that deform the rocks of the eastern domain, and the thrust is also overprinted by normal faults that obscure the original thrust geometries along much of its trace. A minimum age of 78 Ma for the fault is inferred from cross-cutting late Cretaceous plutons (Hyndman and others, 1982; Desmarais, 1983; Marvin and others, 1989; Wallace and others, 1992).

Western Structural Domain

West of the Georgetown-Philipsburg thrust is the Sapphire allochthon, mostly composed of gently folded, low-grade, Mesoproterozoic Belt Supergroup rocks intruded by late Cretaceous to early Tertiary plutons. However, the Sapphire allochthon is clearly not an intact block. It is complexly deformed by faults and shear zones of several types: 1) major reverse faults like the Stony Lake thrust; 2) complex anastomosing fault systems that contain both reverse and normal faults, represented by the Ranch Creek fault system; 3) the NE-striking, near vertical, locally mylonitic Skalkaho shear zone; 4) low-angle younger-over-older normal(?) faults, exemplified by the bedding-parallel Shadow Lake and Burnt Fork detachments, and by the discordant Railroad Creek detachment; 5) high-angle normal(?) faults such as the Daly Creek fault and basin-bounding upper Willow Creek fault. In addition, an enigmatic area of kyanite-bearing, Belt-protolith metamorphic rock exists near the western border of the map in the upper plate of the Bitterroot metamorphic core complex. The gently east-dipping Bitterroot detachment fault defines the western boundary of the Sapphire allochthon and is located just west of the map area. The southwestern corner of the map is composed mostly of late Cretaceous to early Tertiary granitic plutons that postdate all but the high-angle normal(?) faults. On the east slope of the Sapphire Range is the rhyolitic Eocene(?) Rock Creek volcanic field, the probable source of the sapphires (Berg and Dahy, 2002) for which the mountains are named.

Stratigraphy

Middle Proterozoic Belt Supergroup sedimentary and metasedimentary rocks dominate the map area, and Belt nomenclature from type localities in northwestern Montana has been applied to these rocks. Of particular significance is the affirmation of Ravalli Group rocks (Revett Formation?) in the Anaconda Range and southern Sapphire Range. These rocks bring the exposed Belt section thickness to more than 6,100 m (20,000 ft) in the western part of the Philipsburg quadrangle, not including possible lower Belt rocks buried beneath the surface. However, in the eastern domain, as discussed above, the thickness of the Belt section has been thinned by a combination of pre-middle Cambrian erosion and Cretaceous tectonism to less than 4,000 m (13,000 ft), even though the entire lower Belt through Missoula Group section is present. The Paleozoic and Mesozoic sections also appear to have been tectonically attenuated in the eastern domain; they have been eroded off the western domain.

Missoula Group rocks appear to coarsen toward the southern boundary of the Belt Basin that lies only 50 km (30 miles) south of the Philipsburg quadrangle. Both the Mount Shields member 2 and the Bonner Formation contain significant conglomerate in the Anaconda and southern Sapphire Ranges. The McNamara Formation, an argillite-rich unit at its type locality near Missoula, becomes a medium-grained feldspathic arenite in the southern Sapphire Range and near Georgetown Lake. In contrast, Ravalli Group quartzites do not display similar southward-coarsening trends.

Metamorphic Rocks

Amphibolite facies regional metamorphic rocks are common in the quadrangle, although previous maps identified them only as their sedimentary equivalents. Because the distribution of metamorphic rocks is so important to interpreting the structural geology, we have attempted to show them on the map as metamorphic equivalents of the various units. Metamorphism probably occurred prior to intrusion of most of the major plutons in the Philipsburg quadrangle (Stuart, 1966; Grice, 2006; Haney, 2008).

In addition, areas of mylonitic foliation are shown along the eastern flank of the Anaconda metamorphic core complex. Areas of significant tectonic breccia are also shown.

Regional Structural Interpretation

The earliest tectonic event that can be documented in the region is gentle (2°-5°) westward tilting and subsequent erosion of the Mesoproterozoic Belt Supergroup before deposition of the middle Cambrian Flathead Formation. Although there are some disconformities present within the Paleozoic and Mesozoic stratigraphic sections, no other major tectonic events can be identified until the start of the Cretaceous Sevier orogeny. During Sevier orogenesis, east-directed thrust systems like the Stony Lake, Ranch Creek, and Georgetown-Philipsburg thickened the crust and buried the footwall rocks (the eastern domain) to mid-crustal depths beneath the rocks of the western domain. The footwall rocks then underwent high-pressure metamorphism followed by high-temperature, low-pressure metamorphism that coincided with the bedding-parallel fabrics that are associated with the tectonically attenuated stratigraphic section (Kalakay and others, 2003; Grice, 2006). The thinning of the entire >12,200-meter-thick (40,000 ft) metasedimentary section, the faults and shear zones that always omit and never duplicate section, and the dominance of pure shear (coaxial strain) fabrics over simple shear (non-coaxial strain) fabrics suggest to us that the thin stratigraphic section and bedding-parallel fabrics resulted from a period of synorogenic, late Cretaceous extension that occurred in a convergent tectonic setting synchronously with thrusting in the foreland to the east. In fact, there is evidence that some thrusting in the Philipsburg region was coeval with or postdates this extension: 1) detachment faults are duplicated by later thrusts (Lonn and McDonald, 2004a); and 2) similar bedding-parallel faults omit the Snowslip and Shepard Formations on parts of both the hanging wall and footwall of the Georgetown thrust. Hodges and Walker (1992) cite extensive evidence for similar late Cretaceous extension synchronous with thrusting in other areas of the Sevier hinterland, while numerous studies in the Andes and Himalaya have documented the occurrence of active extension in a convergent setting (Dalmayrac and Molnar, 1981; Burchfiel and Royden, 1985; McNulty and Farber, 2002). The postulated late Cretaceous extension may have been facilitated by thermal heating that resulted from crustal thickening and the emplacement of the earliest plutons; in turn, the extension may have generated more plutonism, represented by the voluminous 75-60 Ma intrusions, through decompression melting.

Although some folding undoubtedly occurred during thrusting, the puzzling, west-vergent folds formed during or after most of the thrusting and the proposed extensional structures. The folds may be synchronous with many of the sheet-like, 75-65 Ma intrusions. These folds that verge west--the wrong way--have been difficult to explain. Although they have been attributed to thin-skinned thrust tectonics (Emmons and Calkins, 1913; Csejtey, 1962; Flood, 1974; Wallace and others, 1992), they may represent hot, ductile middle crust (infrastructure) that continued to plastically deform beneath the brittle, cold, upper crust (superstructure) after deformation in the superstructure had ceased (Culshaw and others, 2006).

Convergent tectonism in the region ended in the Paleocene (Harlan and others, 1988) and was immediately followed by crustal extension represented by the Eocene Anaconda metamorphic core complex (O'Neill and others, 2002, 2004). The main Anaconda detachment initiated at about 53 Ma and the mylonitic shear zone was active until at least 47 Ma, and possibly until 30 Ma (Grice and others, 2004; Grice, 2006). The Bitterroot metamorphic core complex just beyond the western border of the Philipsburg quadrangle developed at the same time, and the two are thought to be "nested" core complexes (Foster and others, 2007). Eocene Lowland Creek volcanic rocks (unit Tlc) interfinger with coarse clastic and landslide deposits of the Anaconda beds (unit Tac) that were derived from unroofing of the Anaconda core complex (O'Neill and others, 2004; O'Neill, 2005). Rhyolitic rocks of the Rock Creek volcanic field are probably also of Eocene age.

Most high-angle and listric normal faults appear to be Eocene and younger. Some bound Tertiary valleys like the Upper Willow Creek Valley. Others, like those of the Ranch Creek fault zone and the Georgetown thrust zone, merge and anastomose with reverse faults, and are thought to represent normal-sense reactivation of thrust faults (Lewis, 1998b), although some could have formed synchronously with the thrusts through a constructional strain/extrusion process (Reid and others, 1995; Froitzheim and others, 2006; Lonn and others, 2007). Voluminous sedimentary deposits (units Ts, Tac, Taf) filled basins developed by the Tertiary normal faults.