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).

**Kqd QUARTZ DIORITE (LATE CRETACEOUS)**
- Hornblende-biotite quartz diorite, diorite, and granodiorite. Greenish-gray, micaceous, tabular and lensoidal, hummocky cross-stratification. Thickness 1.5-7.5 m (5-25 ft).

**Kqd PORPHYRITIC GRANODIORITE (LATE CRETACEOUS)**
- Patches of poorly sorted cobbles, boulders, and sand resulting from placer mining operations. Thickness 1.5-7.5 m (5-25 ft).

**Kgd GRANODIORITIC ROCKS (LATE CRETACEOUS)**
- Mostly well-rounded, well-sorted boulders, cobbles, sand, and silt deposited by streamflow processes. Thickness 1.5-15.0 m (5-25 ft).

**Kgd PORPHYRITIC GRANODIORITE (LATE CRETACEOUS)**
- Accumulations of angular boulders below cliffs. Thickness 1.5-15.0 m (5-25 ft).

**Kgh 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 coarser-grained channel deposits. In some areas, older alluvial deposits (Qgh) are not divided from Qgh.

**Kgp 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.

**Kgv ALLUVIAL FAN DEPOSITS (EARLY HOLOCENE AND LATE PLEISTOCENE)**
- Sandstones often contain dark chert grains or volcanic fragments. The lower Colorado Group includes dark-gray to black fissile shale underlain by dark 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).

**Kgc ROCK GLACIER DEPOSITS (HOLOCENE)**
- Unsorted and unstratified mixtures of mud and boulders transported by mass movement down steep slopes. Characterized by irregular topography.

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- Unsorted and unstratified mixtures of mud and boulders transported by mass movement down steep slopes. Characterized by irregular topography.

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

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

**Kgs DEBRIS FLOW DEPOSITS (PLEISTOCENE)**
- Mostly well-rounded, well-sorted boulders and cobbles transported by mass movement down steep slopes. Characterized by irregular topography.

**Kgs DEBRIS FLOW DEPOSITS (PLEISTOCENE)**
- Locally accumulations of angular boulders emplaced by flow of an ice core. Active and inactive rock glaciers are not divided.

**Kgs DEBRIS FLOW DEPOSITS (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 (Qgt).

**Kgs DEBRIS FLOW DEPOSITS (PLEISTOCENE)**
- Moderately to well-sorted, well-rounded, well-stratified sand, pebbles, and boulders deposited by streams flowing within, on, and marginal to glacial. Topographic surfaces tend to be hummocky and contain ridges and kettles. Disturbed in the field from glacial till (Qgt) by the roundness of the clasts and by the deposits' well-drained nature. Include some...
REFERENCES


Langton, C.M., 1935, Geology of the northeastern part of the Idaho Batholith and adjacent region in Montana: Journal of Geology, v. 43, p. 35-60, map scale 1:42,000.


ALLUVAL 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.

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

GRANODIORITIC ROCKS (Tertiay EARLY TERTIARY AND LATE CRETACEOUS)
QnttGranodioritic rocks weather and form rounded to sub-rounded cobbles and boulders up to 80 cm (3 ft) in diameter. In some localities, these rocks form locally thick deposits that are mantled by overlying younger deposits. These rocks are mostly composed of quartz, feldspar, and biotite, with minor amounts of hornblende and garnet. The quartz is often partially recrystallized, and the feldspar is typically microcline.

GRANITIC ROCKS (EARLY TERTIARY AND LATE CRETACEOUS)
QnttGranitic rocks are composed of quartz, feldspar, and biotite. They are typically fine-grained and often exhibit a granular texture. These rocks are resistant to weathering and form steep cliffs and rocky outcrops along riverbanks and stream beds.

SIXMILE CREEK FORMATION (PLIOCENE AND MIocene)
Mostly conglomerate with some sandstone and siltstone. Commonly垫 the remnant Tertiary surfaces.

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

ANACONDA BEDS, INFORMAL (EOCENE?)
Unstratifiable deposits of alluvium. Poorly to well-sorted, rounded to sub-rounded cobbles, sand, silt, and clay. These deposits form extensive, low-relief fans that extend for many kilometers from their source areas.

RHYOLITE (EOCENE?)
Rhyolite is a dense, fine-grained volcanic rock composed of predominantly quartz, with subordinate plagioclase and biotite. It is typically dark brown or black in color.

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

TUFF BRECCIA (EOCENE?)
Poorly stratified, poorly sorted, mostly sub-angular, angular to sub-rounded cobbles, sand, silt, and clay. These deposits are locally interbedded with volcanic ash and pumice.

RHYOLITE BRECCIA (EOCENE?)
Rhyolite flows and tuff that contain abundant biotite phenoocrysts and sparse feldspar and quartz phenocrysts. The tuff predominantly contains minor volcanic fragments. The rhyolite contains a significant amount of volcanic ash and pumice.

TUFFYLITE (EOCENE?)
Rhyolite flows and tuff that contain abundant biotite phenoocrysts and sparse feldspar and quartz phenocrysts. The tuff predominantly contains minor volcanic fragments. The rhyolite contains a significant amount of volcanic ash and pumice.

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

RHYOLITE TUFF (EOCENE?)
Rhyolite flows and tuff that contain abundant biotite phenoocrysts and sparse feldspar and quartz phenocrysts. The tuff predominantly contains minor volcanic fragments. The rhyolite contains a significant amount of volcanic ash and pumice.

BIOTITE-MUSCOVITE MARBLE (EOCENE AND PALEOCENE)
Equigranular and porphyroclastic biotite-muscovite granite. Mylonitic foliation is present within and adjacent to the Skalkaho Canyon detachment fault.

GRANODIORITIC ROCKS (EOCENE AND PALEOCENE)
QnttGranodioritic rocks consist of quartz, feldspar, and biotite. They are typically fine-grained and exhibit a granular texture. These rocks are resistant to weathering and form steep cliffs and rocky outcrops along riverbanks and stream beds.

GRANITIC ROCKS (EARLY TERTIARY AND LATE CRETACEOUS)
QnttGranitic rocks are composed of quartz, feldspar, and biotite. They are typically fine-grained and exhibit a granular texture. These rocks are resistant to weathering and form steep cliffs and rocky outcrops along riverbanks and stream beds.

QUARRIES AND QUARTZITES (EOCENE AND PLEISTOCENE)
QnttQuarries and quartzites are typically fine-grained and exhibit a granular texture. These rocks are resistant to weathering and form steep cliffs and rocky outcrops along riverbanks and stream beds.
 sediments. The lower part is red, thinly bedded dolomitic limestones. Estimated to be 152 m (500 ft) thick.

However, these cycles are more easily recognized by wavy but not green argillite, by white quartzite, 30 ft thick, and by weathered-out mud cracks. Green and red, dolomitic packages of silts and quartzites are present in beds less than one centimeter thick to coarse-grained quartizes that are red mudcracks and mud chips are

In the Bonner Formation, the pale lithology is characterized by red mudcracks and mud chips are n't as much as 914 m (3,000 ft). However, these cycles are more easily recognized by wavy but not green argillite, by white quartzite, 30 ft thick, and by weathered-out mud cracks. Green and red, dolomitic packages of silts and quartzites are present in beds less than one centimeter thick to coarse-grained quartizes that are red mudcracks and mud chips are

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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 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 Sherriff, 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 geometry 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 pseudomorphs (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 a series of bedding-parallel fabrics and structures that include concordant mylonite shear zones that cut out stratigraphic section, zones of vertical shortening that flatten the units through pure shear and plastic flow, and brittle-brittle parallel faults that place younger units over older units (Lonn and McDonald, 2004a, 2005; Lonn and Lewis, 2009). Parallel solid-state fabrics are present in the oldest (75 Ma) late Cretaceous plutons (units KgdpKdg) 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; 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 ... (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 Mesoprotorozoic 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 (Grice 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 allolchoth, mostly composed of gently folded, low-grade, Mesoprotorozoic Belt Supergroup rocks intruded by late Cretaceous to early Tertiary plutons. However, the Sapphire allolchoth is clearly not an intact block. It is complexly deformed by faults and shear zones of several types: 1) major
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, this 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 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, 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 and are thought to represent normal-sense reactivation of thrust faults (Lewis, 1998b), although some could have formed synchronously with the thrusts through a constructive strain/extrusion process (Reid ... 2007). Voluminous sedimentary deposits (units Ts, Tac, Taf) filled basins developed by the Tertiary normal faults.

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 (2º -5º) westward tilting and subsequent erosion of the Mesoproterozoic Belt Supergroup before deposition of the mid-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 roots 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) metamorphic section, the faults and shear zones that always omit and never duplicate, 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 Phillipsburg region was coeval with or postdates this extension: 1) detachment faults are duplicated by later thrusts (Lonn and McDonald, 2004a); and 2) similar beddingparallel faults omit the Snowspit and Shepard formations on both of 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 (Dalmayr and Mohr, 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 structural systems. 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 Calcite, 1913, Cjiey, 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, 2004, 2005). 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 Phillipsburg 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 Tc) interfinger with coarse clastic and landslide deposits of the Anaconda bed (unit Tc) 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). However, some faults have formed synchronously with the thrusts through a constructive strain/extrusion process (Red and others, 1995, Frotztem and others, 2004; Lonn and others, 2007). Voluminous sedimentary deposits (units Ts, Tc, Taf) filled basins developed by the Tertiary normal faults.