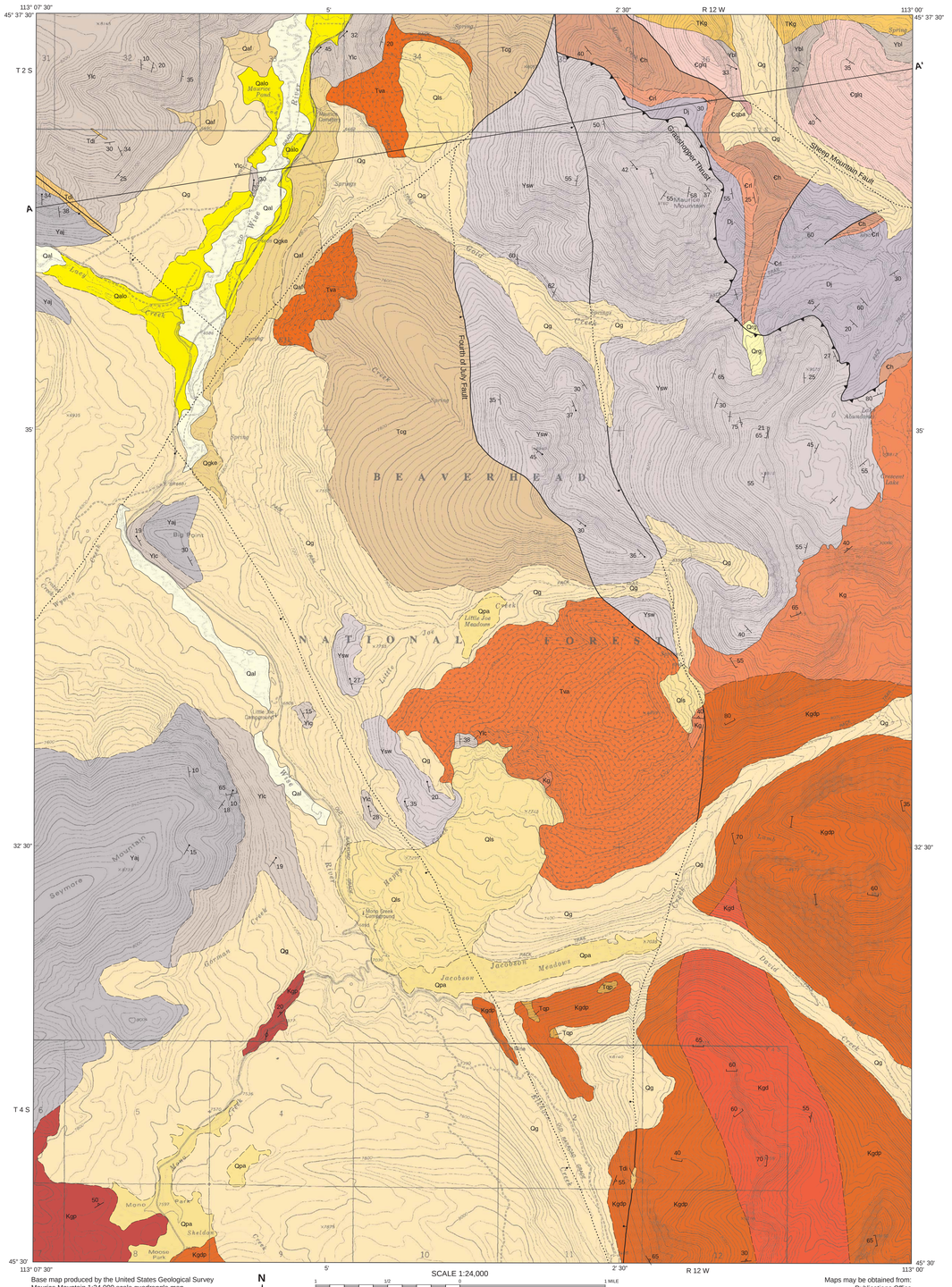

Base map produced by the United States Geological Survey
Maurice Mountain 1:24,000 scale quadrangle map
Control by: USGS, NOS/NOAA and USFS
Compiled from aerial photographs taken 1967
Field checked: 1974. Map edited: 1978
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 1°28' West
1988 Magnetic NorthDeclination: 18° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

SCALE 1:24,000
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Maps may be obtained from:
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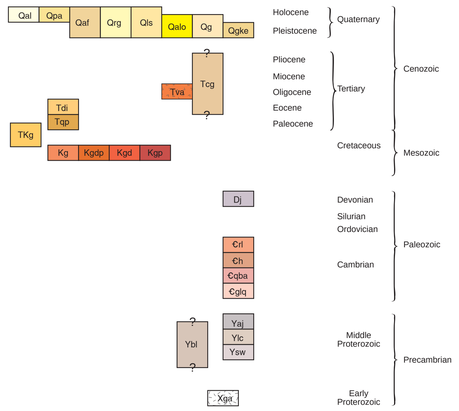
CORRELATION DIAGRAM



MAP SYMBOLS

- Contact: dashed where approximately located
- Fault: dashed where approximately located, dotted where concealed
- Normal fault: dashed where approximately located, dotted where concealed, bar and ball on downthrown side
- Reverse or thrust fault: dashed where approximately located; dotted where concealed, teeth on upthrown block
- 38 — Strike and dip of inclined beds
- 35 — Strike and dip of bedding where stratigraphic tops were confirmed using primary sedimentary structures
- 75 — Overturned bedding
- Vertical bedding
- 40 — Strike and dip of igneous foliation
- Strike of vertical igneous foliation
- 35 — Inclined cleavage
- Vertical cleavage

Figure 1. Location of the Maurice Mountain quadrangle with respect to the Belt Basin margin and Grasshopper thrust.

PREVIOUS MAPPING

1. Berger and others, 1983
2. Pearson and Zen, 1985
3. Calbeck, 1975
4. Ruppel and others, 1993 (entire quadrangle)
5. Zen, 1988 (entire quadrangle)

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

INTRODUCTION

A collaborative Montana Bureau of Mines and Geology–Idaho Geological Survey (MBMG–IGS) mapping project began in 2007 to resolve some long-standing controversies concerning the relationships between two immensely thick, dissimilar, Mesoproterozoic sedimentary sequences: the Lemhi Group and the Belt Supergroup (Ruppel, 1975; Winston and others, 1999; Evans and Green, 2003; O'Neill and others, 2007; Burmester and others, 2013). The Maurice Mountain 7.5' quadrangle occupies a key location for study of these Mesoproterozoic strata, as well as for examination of important Proterozoic through Tertiary tectonic features. In the Anaconda Range, northwest of the Maurice Mountain quadrangle, Mesoproterozoic Belt Supergroup rocks are exposed (Ruppel and others, 1993; Lonn and McDonald, 2004) that extend northward into Canada. In the West Pioneer and Beaverhead Mountains to the south are strata are assigned to the Mesoproterozoic Lemhi subbasin stratigraphic succession, which includes the Lemhi Group and overlying units (Ruppel, 1975; Lonn and others, in review; Burmester and others, 2013). The Maurice Mountain quadrangle (fig. 1) also appears to straddle two important tectonic features: the eastern margin of the Proterozoic Belt basin margin (McDonald and others, 2012; McDonald and Lonn, 2013, 2014) and the Cretaceous Grasshopper thrust fault (Ruppel and others, 1993).

GEOLOGIC SUMMARY

Mesoproterozoic sedimentary rocks of the Maurice Mountain 7.5' quadrangle are correlated with strata of the upper part of the Lemhi subbasin succession (Burmester and others, 2013; Lonn and others, in review) which include the Swauger, Lawson Creek, and Apple Creek Formations overlying the type Lemhi Group (Ruppel, 1975). In Mesoproterozoic time, a >15-km-thick section of mostly siliciclastic sediments was deposited in the Lemhi subbasin (fig. 1), a southern arm of the larger Belt basin (Burmester and others, 2013). The eastern margin of the Lemhi subbasin was located immediately to the east of the quadrangle (McDonald and others, 2012; McDonald and Lonn, 2013, 2014) and composed of Archean and Paleoproterozoic crystalline rocks. In Cretaceous time, the thick Lemhi quartzite succession was thrust eastward over the Mesoproterozoic basin margin along the Grasshopper thrust system (Ruppel and others, 1993). The leading edge of the Grasshopper thrust system is exposed in the northeastern part of the quadrangle. Although the hanging wall of the Grasshopper thrust contains the thick succession of Lemhi strata, its footwall contains only Mesoproterozoic Black Lion Formation, a wedge of coarse conglomerate deposited on crystalline basement rocks (cross section A–A') along the steep margin of the Belt–Lemhi basin (McDonald and others, 2012; McDonald and Lonn, 2013, 2014). Cretaceous compressional tectonism formed the folds in the Paleozoic and Mesoproterozoic sedimentary rocks, as well as the Sheep Mountain fault (described by McDonald and others, 2012, and named herein), which is itself folded and cuts out parts of the lower Paleozoic section (cross section A–A').

Granitic rocks of the Pioneer batholith intruded the deformed sedimentary rocks in the southern and eastern part of the quadrangle beginning in the Late Cretaceous and continuing until the Eocene. Tertiary volcanic ash deposits (Oligocene?) and conglomerate (Eocene and younger?) are preserved in the hanging wall of the north–south, down-to-the-west Fourth of July normal fault zone that developed during Tertiary extensional tectonism. Finally, Pleistocene glaciers advanced northward from the high country to fill the Wise River Valley, leaving extensive deposits of till and glaciofluvial material throughout the quadrangle.

DESCRIPTION OF MAP UNITS

QUATERNARY AND TERTIARY DEPOSITS

Qal **Alluvium (Holocene)**—Gravel, sand, silt, and clay in modern stream channels and floodplains. Thickness less than 100 m (330 ft) thick.

Qpa **Paludal deposit (Holocene)**—Sand, silt, and organic matter deposited in swamp, marsh, pond, or lake. Thickness probably less than 10 m (33 ft).

Qaf **Alluvial fan deposits (Holocene and Pleistocene)**—Subangular to subrounded, poorly sorted, cobble to boulder gravel, silt, and sand. Thickness probably less than 60 m (200 ft).

Qrg **Rock glacier deposit (Holocene and Pleistocene)**—Angular rock debris and boulders in lobate deposit. Active and inactive rock glaciers not distinguished. Thickness less than 18 m (60 ft).

Qls **Landslide deposit (Holocene and Pleistocene)**—Unsorted mixture of silt, clay, sand, gravel, and boulders. Typically characterized by hummocky topography and found in areas of unconsolidated volcanic rocks (unit Tva). Thickness probably less than 30 m (100 ft).

Qalo **Older alluvium (Holocene and Pleistocene)**—Stream and floodplain deposits along the Wise River that are above the modern floodplain. Mostly sand and subrounded to rounded, moderately sorted, sandy pebble to cobble gravel. Includes glacial outwash. Thickness unknown, but probably less than 30 m (100 ft).

Qg **Glacial deposits, undivided (Holocene and Pleistocene)**—Most is unsorted sandy to clayey boulder till with subangular to subrounded clasts. Characterized by huge granite boulders derived from the southern headwaters of the Wise River in the East Pioneer Mountains. Most till is of Pinedale age, but unit also includes younger glacial and periglacial deposits in higher elevations. Also includes minor outwash, fan, kame, and esker deposits, and older till. As thick as 100 m (330 ft).

Qgke **Kame and esker deposits (Pleistocene)**—Sand and subrounded to rounded, moderately sorted, sandy pebble to cobble gravel deposited in kames, eskers, and ice-margin channels. As much as 100 m (330 ft) thick.

Tcg **Conglomerate (Pliocene? to Eocene?)**—Unconsolidated, poorly bedded, poorly sorted gravel deposits characterized by subangular to subrounded quartzite boulders. Occurs on the downthrown western side of the Fourth of July fault system and was probably deposited in a system of coalescing alluvial fans. Overlies unit Tva in the northern part of the map, but age relationships in the central part are indeterminate. Possibly as much as 300 m (1,000 ft) thick.

Tva **Volcanic ash deposit (Oligocene)**—Yellowish clay containing 5–20% silt, fine glass shards, tiny biotite flakes, sand-sized grains of white feldspar (Calbeck, 1975). Also includes thin intervals that contain matrix-supported well-rounded quartzite pebbles, cobbles and boulders. Zen (1988) interpreted the bouldery layers as fluvial deposits interbedded within thick air fall ash deposits; Roe (2010) suggested that that the fluvial gravels are interbedded with tuffaceous debris flows. Roe dated correlative ashes on the north-adjacent Stine Mountain 7.5' quadrangle at 29.920 ± 0.023 Ma. Unit occurs on the downthrown western side of the Fourth of July fault system. Thickness at least 100 m (330 ft).

PALEOZOIC STRATA

A severely deformed and incomplete Middle Cambrian to Devonian section is present in the footwall of the Grasshopper thrust in the northeastern part of the quadrangle. The Sheep Mountain fault developed at a low angle to bedding and omits various Cambrian units (McDonald and others, 2012).

Dj **Jefferson Formation (Devonian)**—Dark gray, yellow, and white, sugary dolomite and limestone, commonly bleached and recrystallized to white marble. Dark gray dolomite distinguishes this unit from the Hasmark Formation (unit Ch). Strongly deformed, with numerous intraformational faults, abundant tectonic breccia, and tight folds. Deformation makes thickness estimates problematic, but probably more than 300 m (1,000 ft) thick.

Crl **Red Lion Formation (Cambrian)**—Discontinuous, multi-colored and lithologically variable unit that includes red dolomite with thin maroon anastomosing shale layers, shaly conglomerate containing limestone and mud-chip intraclasts, reddish calcareous silty shale, and calcareous to non-calcareous sandstone and quartzite. Thickness 0–20 m (0–65 ft).

Ch **Hasmark Formation (Cambrian)**—Light gray to white thinly laminated to massive dolomite with minor magnesium limestone intervals. Weathers very light gray with a smooth, laminated surface. Thickness variable due to deformation, ranging from 200 to 500 m (650–1,640 ft).

Cqba **Quartzite and argillite (Cambrian)**—Quartzite and black argillite in couplets (cm-scale) and couples (dm-scale). Argillite has a lumpy appearance and locally contains trace fossils. Quartzite is white, fine-grained, and well-sorted. Exposed sections on the east-adjacent Butte South quadrangle (McDonald and others, 2012) exhibit evidence of a fault, here named the Sheep Mountain Fault, which is sub-parallel to bedding and omits stratigraphic section. As a result, less than 25 m (80 ft) is exposed in the quadrangle.

Cglq **Quartzite of Grace Lake (Cambrian?)**—White to light gray, fine- to medium-grained quartzite. Contains coarse intervals with rounded quartzite pebbles and angular grains of quartzite, quartz, and feldspar; some beds of "grit." Lacks the pink and red quartzite and brick-red chert clasts of the Black Lion Formation (unit Ybl). Grains are subrounded to sub-angular, and moderately to well-sorted, although coarse intervals are poorly sorted. Contains abundant well-rounded quartz grains. In hand sample, the finer-grained intervals appear feldspar-poor, but slabbed and stained samples contained 15–25 percent K-spar, and 5–10 percent plagioclase. Flat laminations are common, as are trough crossbeds in the coarse intervals. Base is exposed at Grace Lake, just east of the map, where a low-angle unconformity with the underlying Black Lion Formation is clearly visible. Appears to grade upward into the quartzite and argillite of unit Cqba at Grace Lake, but on the Maurice Mountain quadrangle a fault separates the two. Equivalent to the quartzite of Grace Lake of Ruppel and others (1993), and the Cambrian or Proterozoic quartzite of Pearson and Zen (1985). Thickness unknown but at least 75 m (244 ft) exposed at Grace Lake east of the quadrangle. After McDonald and others (2012).

PROTEROZOIC UNITS

Low-grade metasedimentary rocks of Mesoproterozoic age underlie much of the Maurice Mountain quadrangle. The MBMG–IGS collaborative team, after completing detailed mapping across the Idaho–Montana border in the Beaverhead Range and undertaking reconnaissance work in the Lemhi Range, now correlates all Proterozoic strata within the Maurice Mountain quadrangle with units of the Lemhi subbasin (Burmester and others, 2013) that lie stratigraphically above the Lemhi Group (Ruppel, 1975). These units—the Swauger, Lawson Creek, and Apple Creek Formations—are present in the hanging wall of the Grasshopper thrust. In the footwall, the Mesoproterozoic is represented by the Black Lion Formation, thought to be a basin-margin facies deposited along the edge of the Lemhi subbasin.

Yaj **Jahnke Lake member, Apple Creek Formation (Mesoproterozoic)**—Gray, pale green or light red to pink, thick-bedded, very fine- to medium-grained, well-sorted, very feldspathic quartzite. Bedding is often difficult to see, but where visible is commonly defined by dark laminations rich in hematite grains. Climbing ripple cross-lamination, flat lamination, and convolute bedding resulting from soft sediment deformation are common. Thin skins of green argillite commonly separate the 0.5–1-m-thick quartzite beds, and thin mud rip-ups are common in some intervals. Contains rare coarse floating grains of well-rounded quartz. Rarely, coarse to very coarse grains of quartz and granitic rock are concentrated along bedding planes in layers a few grains thick. Feldspar content averages about 50 percent, with plagioclase more abundant than potassium feldspar. Lower contact is gradational with the underlying Lawson Creek Formation (unit Ylc). Upper contact not exposed, and only a thin stratigraphic section is present in the quadrangle. The unit is correlated with the lowest part of the redefined Apple Creek Formation in the Lemhi Range (Burmester and others, 2013). On the south-adjacent Salmon 30' x 60' quadrangle (Lonn and others, in review),where the Jahnke Lake member is also the uppermost Mesoproterozoic unit, thickness ranges from 0 m to 4,300 m (0 to 14,000 ft).

Ylc **Lawson Creek Formation (Mesoproterozoic)**—Characterized by couplets (cm-scale) and couples (dm-scale) of fine- to medium-grained white to pink quartzite and red, purple, black, and green argillite. Lenticular and flaser bedding are common and characteristic. Mud rip-up clasts are locally common, and some are as much as 15 cm in diameter. Thick intervals of medium-grained, thick-bedded (m-scale) quartzite are commonly interbedded with the argillite-rich intervals. The quartzite intervals appear similar to the upper part of the underlying Swauger Formation (unit Ysw), but quartz typically comprises a large percentage of the grains (up to 93 percent) in contrast to the feldspathic Swauger Formation. Except in the uppermost part, potassium feldspar is more abundant than plagioclase. The lower contact is placed at the bottom of the thin-bedded argillite-rich interval that gradationally overlies the Swauger Formation. The upper contact is placed at the top of the uppermost argillite-rich strata beneath the dominantly thick-bedded fine-grained quartzite of the Jahnke Lake member of the Apple Creek Formation (unit Yaj). Equivalent to the Sequence of Big Point of Zen (1988). Also tentatively correlated with the McNamara Formation of the Missoula Group, Belt Supergroup. An unfaulted stratigraphic section is not present in the Maurice Mountain quadrangle, but thickness is as much as 2,150 m (7,050 ft) in the south-adjacent Salmon 30' x 60' quadrangle (Lonn and others, in review).

Ysw **Swauger Formation (Mesoproterozoic)**—Lower part is multicolored (pink, white, red, and purple) thick-bedded, poorly sorted, cross-bedded, coarse-grained quartzite containing numerous pebble-bearing intervals as well as intervals of thin-bedded, flat laminated, fine-grained quartzite and siltite. Coarse, floating, well-rounded quartz grains and chalky white feldspar grains are obvious in hand sample. Quartz grains are well-rounded, but feldspar grains are angular, suggesting two source areas. Pink quartz grains, red jasper grains, detrital muscovite, and thick mud rip-ups are common. Rare argillite beds commonly contain desiccation cracks. Potassium feldspar is the only feldspar present (Calbeck, 1975). Upper part is pink to gray, thick bedded, medium- to fine-grained quartzite, massive to trough-crossbedded. Feldspar content is variable, with dominant potassium feldspar and a few percent plagioclase always present (Calbeck, 1975). Pink quartz and red chert grains are common. Thick intervals of thick-bedded, massive, nearly pure quartzite are also present. Coarse, well-rounded floating grains of quartz are common throughout. Twenty Swauger Formation samples, slabbed and stained for potassium feldspar, showed highly variable composition ranging from 5 percent to 60 percent feldspar, but potassium feldspar is everywhere more abundant than plagioclase. Equivalent to Zen's (1988) Boner Knob and Maurice Mountain quartzites, and to Calbeck's (1975) Belt 1 and 2. The Swauger Formation is tentatively correlated with the Bonner Formation of the Missoula Group, Belt Supergroup, on the basis of lithologic similarity and stratigraphic position. Upper contact gradational with overlying Lawson Creek Formation (unit Ylc); lower contact not exposed. Calbeck (1975) estimated a thickness of at least 1,600 m (5,200 ft); on the south-adjacent Salmon 30' x 60' quadrangle (Lonn and others, in review), the Swauger Formation is as much as 5,500 m (18,000 ft) thick.

Ybl **Black Lion Formation (Mesoproterozoic)**—Pink, green, and purple conglomerate containing abundant multi-colored, subangular to rounded lithic fragments. Typically prominently crossbedded with both trough and high-angle planar crossbeds. Composition is highly variable, reflecting local source areas. Abundant gritty intervals contain angular gneissic, granitic, and dark-colored lithic clasts. Contains distinctive brick red laminated chert (siltstone?) and pink to white quartzite clasts that are usually rounded; these clasts are rare to absent in the overlying Grace Lake quartzite (Unit Cglq). Contains intervals of light gray, medium-grained, quartz-rich, sub-angular to sub-rounded, well-sorted quartzite with abundant coarse round quartz grains. The upper contact is an angular unconformity in the Grace Lake area just east of the quadrangle (McDonald and others, 2012). The lower contact appears to be unconformable with the underlying Paleoproterozoic gneiss at Sheep Mountain northeast of the quadrangle (McDonald and others, 2012). Present only in the footwall of the Grasshopper thrust in the northeastern corner of the quadrangle. Resembles the LaHood Formation of the Highland Mountains, and interpreted to be a similar restricted facies deposited along a steep margin of the Belt–Lemhi basin (McDonald and Lonn, 2013, 2014). Thought to grade laterally west into the Swauger and possibly other Mesoproterozoic formations, but now separated from them by the Grasshopper thrust system. As much as 500 m (1,625 ft) thick (Zen, 1988).

Xgä **Gneiss and amphibolite (Paleoproterozoic)**—Crystalline basement rocks shown only on cross section A–A'.

INTRUSIVE IGNEOUS ROCKS

Intrusive rocks are extensive in the southern and eastern parts of the quadrangle, where they form part of the Pioneer Batholith. Distribution and descriptions of these igneous units were modified from Zen (1988) and Pearson and Zen (1985).

Tdi **Mafic dike (Eocene?)**—Dark gray altered dikes containing olivine and/or augite, lath-shaped feldspar, pyroxene, and opaque minerals (Zen, 1988). Intrudes a fault zone near the western border of the map and the Fourth of July Fault Zone in the southern part of the map. Similar dikes on the south-adjacent Salmon 30' x 60' quadrangle have been dated at 46 Ma (Richard Gaschnig, written communication, 2009), and a mafic dike in the Pioneer Mountains yielded a whole rock K-Ar age of 51 Ma (Snee, 1978). However, in this area Zen (1988) reported a whole rock Ar^{40}/Ar^{39} thermal release minimum age of 660 Ma for a mafic dike with an unspecified location.

Tqp **Quartz porphyry (Paleocene)**—Rounded 1-cm smoky quartz phenocrysts in a matrix of quartz, feldspar, biotite, euhedral sphene, and apatite (Zen, 1988). Occurs as dikes cutting the Uphill Creek granite (unit Kgdp) in the southeastern part of the map.

TKg **Granite of Clifford Creek (Paleocene and Late Cretaceous)**—Massive, coarse-grained two-mica granite, locally porphyritic. Porphyritic phase has white euhedral potassium feldspar phenocrysts as much as 3 cm long. After Zen, 1988. K-Ar age of 64.9 ± 2.2 Ma (Pearson and Zen, 1975).

Kg **Granite of Grayling Lake (Late Cretaceous)**—Medium- to coarse-grained, pinkish gray granite to granodiorite. Fresh rock shows 1-cm euhedral potassium feldspar phenocrysts in a matrix of white plagioclase, smoky-lilac quartz, biotite, and rare hornblende. Foliation generally defined by alignment of biotite and feldspar. Sharp chilled margin. After Zen (1988). Best age estimates are a K-Ar date of 72.3 ± 2.5 Ma and an Ar^{40}/Ar^{39} date of 72.1 ± 1.6 Ma (Zen, 1988), a K-Ar age of 74.1 ± 2.7 Ma (Marvin and others 1983), and a U-Pb zircon age of 72.17 ± 1.7 Ma (Murphy and others, 2002).

Kgdp **Porphyritic granodiorite of Uphill Creek (Late Cretaceous)**—Gray, porphyritic, medium- to coarse-grained biotite-hornblende granodiorite. Characterized by anhedral megacrysts of potassium feldspar with inclusions of other minerals. This is the largest pluton of the Pioneer batholith. Flow foliation defined by alignment of mafic minerals is poorly to moderately developed. Best age estimates of the unit are an Ar^{40}/Ar^{39} date of 75 Ma (Snee, 1982) and U-Pb zircons ages of 72.2 and 72.17 Ma (Murphy, 2002).

Kgd **Granodiorite of David Creek (Late Cretaceous)**—Gray, medium- to fine-grained, slightly porphyritic biotite-hornblende granite. Appears to cut the Uphill Creek granodiorite (unit Kgdp) in places and grade into it in other places. After Zen (1988).

Kgp **Porphyritic granite of Mono Park (Late Cretaceous)**—Slightly porphyritic biotite granite containing minor hornblende and a few potassium feldspar megacrysts. May grade into Uphill Creek granodiorite (unit Kgdp).

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MBMG Open-File Report 657

Geologic Map of the Maurice Mountain 7.5' Quadrangle Southwestern Montana

Jeffrey D. Lonn

2015