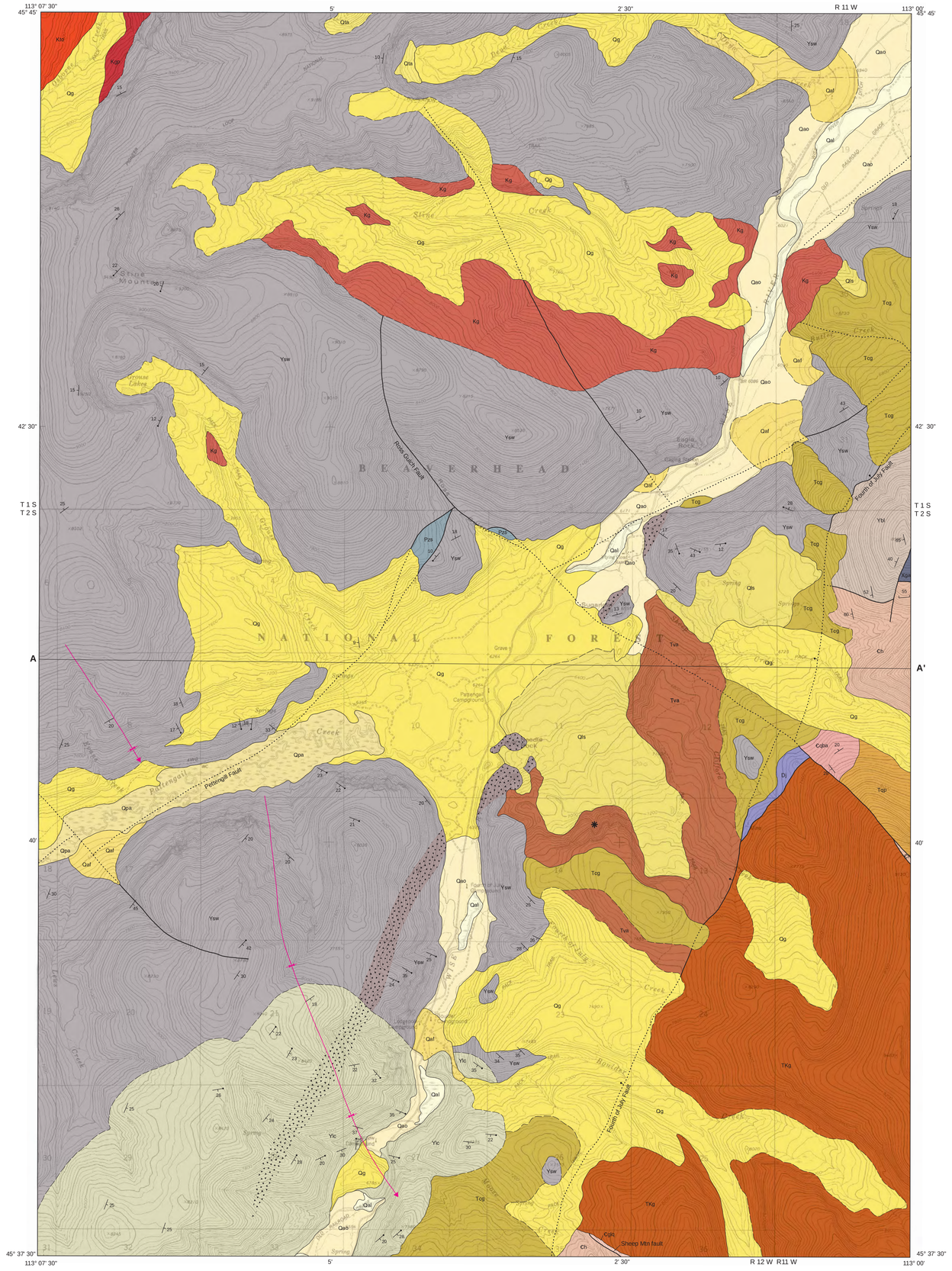

Base map produced by the United States Geological Survey
Stine Mountain 1:24,000 scale quadrangle map
Control by: USGS, NOS/NOAA and USFS
Compiled from aerial photographs taken 1967
Field checked: 1974. Map edited: 1978
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 1°29' West
1994 Magnetic North Declination: 16° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

N

SCALE 1:24,000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Maps may be obtained from:
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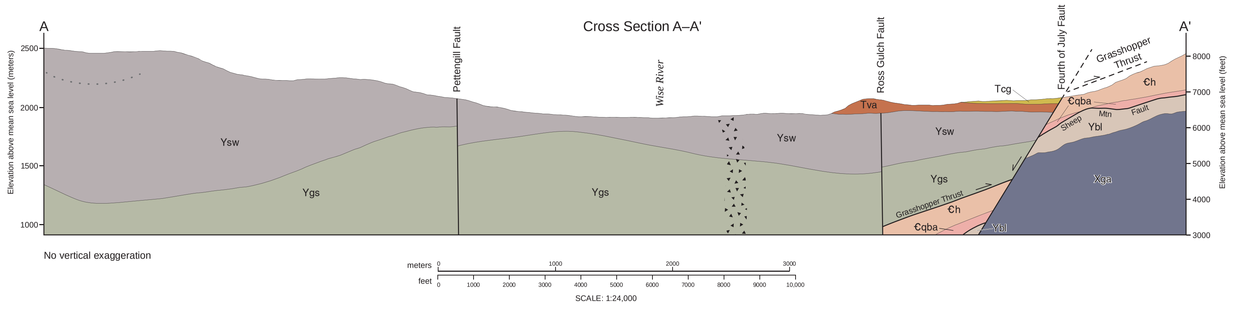
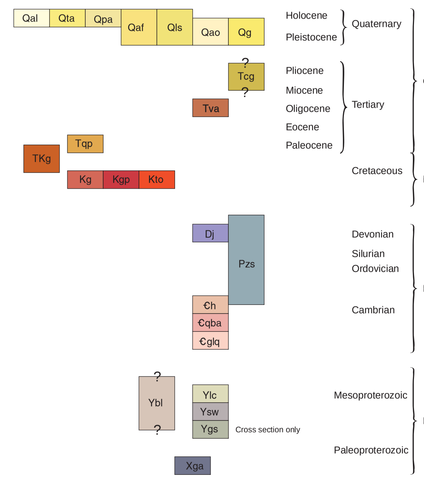


Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G15AC00219. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

GIS production: Yiwen Li and Paul Thale, MBMG. Map layout: Susan Smith, MBMG. Editing: Susan Barth, MBMG.

CORRELATION DIAGRAM



MAP SYMBOLS

Contact: dashed where approximately located

Fault: dotted where concealed

Normal fault: dotted where concealed, bar and ball on downthrown side

Syncline: showing trace of axial plane and plunge direction where known; dotted where concealed

Anticline: showing trace of axial plane and plunge direction where known; dotted where concealed

Strike and dip of inclined beds

Strike and dip of inclined cleavage

Strike and dip of bedding where stratigraphic tops were confirmed using primary sedimentary structures

Tectonic breccia—Lithified quartz-cemented breccia containing angular quartzite clasts and abundant slickensides.

Sample location for 29.920 ± 0.023 Ma U-Pb zircon age reported by Roe (2010)

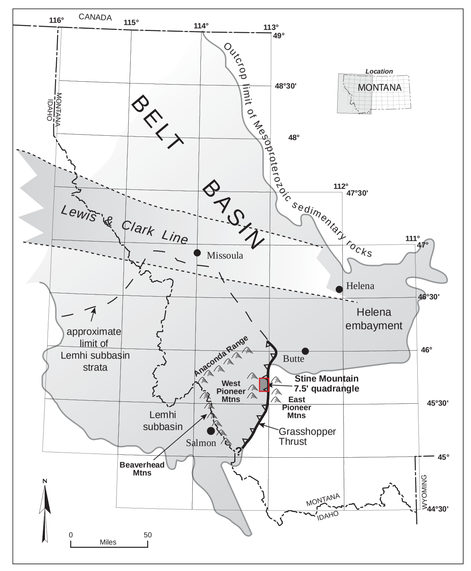
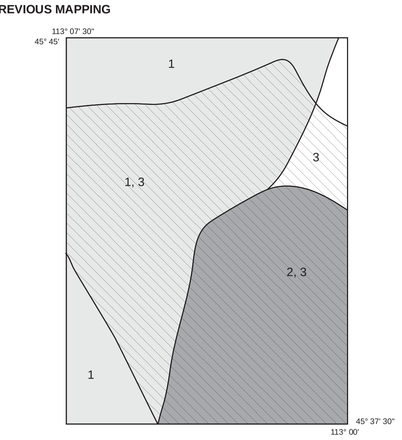


Figure 1. Location of the Stine Mountain quadrangle with respect to the Belt Basin margin and Grasshopper thrust.

PREVIOUS MAPPING



1. Berger and others, 1983
2. Pearson and Zen, 1985
3. Calbeck, 1975

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 relationship between two dissimilar, immensely thick, 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 Stine Mountain 7.5' quadrangle occupies a key location for study of these Mesoproterozoic strata and important Proterozoic through Tertiary tectonic features. Mesoproterozoic Belt Supergroup rocks exposed in the Anaconda Range, northwest of the Stine Mountain quadrangle (Ruppel and others, 1993; Lonn and McDonald, 2004a; Lonn and others, 2009), extend northward into Canada. Strata in the West Pioneer and Beaverhead Mountains to the south belong 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, 2016). The Stine Mountain quadrangle also straddles the boundary of two important tectonic features: the eastern margin of the Proterozoic Belt Basin (McDonald and others, 2012; McDonald and Lonn, 2013, 2014; Lonn, 2014) and the Cretaceous Grasshopper Thrust (Ruppel and others, 1993) (fig. 1).

Note on "Pettengill": On the topographic base used for this map, the stream that runs from the southwest to the northeast through the center of the map is called Pettengail Creek. In a 1996 decision, the United Geological Survey Board on Geographic Names changed the official name of the creek to that of local rancher George Pettengill, who died in 1918. The latter name is used herein.

GEOLOGIC SUMMARY

Much of the Stine Mountain quadrangle is underlain by gently dipping Mesoproterozoic sedimentary rocks. These strata are correlated with the upper part of the Lemhi subbasin succession (Burmester and others, 2013, 2016) which includes the Swauger and Lawson Creek Formations that overlie 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, 2016). The eastern margin of the Lemhi subbasin is located along the eastern edge of the quadrangle (McDonald and others, 2012; McDonald and Lonn, 2013, 2014; Lonn, 2014) and abuts 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 (Ruppel and others, 1993). The Grasshopper Thrust is cut by the Fourth of July Fault as shown on cross section A–A'; the thrust's trace surfaces on the south-adjacent Maurice Mountain quadrangle (Lonn, 2015) and the east-adjacent Butte South 30' x 60' quadrangle (McDonald and others, 2012). Although the hanging wall of the Grasshopper Thrust contains a thick succession of Lemhi strata, its footwall contains only the Mesoproterozoic Black Lion Formation, a wedge of coarse conglomerate deposited on crystalline basement rocks (cross section A–A') along the steep eastern margin of the Belt–Lemhi basin (McDonald and others, 2012; McDonald and Lonn, 2013, 2014).

Cretaceous compressional tectonism formed the Sheep Mountain fault (McDonald and others, 2012; Lonn, 2015), which cuts out parts of the lower Paleozoic section and is itself folded (cross section A–A'), as well as the gentle folds in the Mesoproterozoic rocks. Late Cretaceous to Paleocene granitic rocks of the Pioneer batholith intrude the sedimentary rocks in the southeastern and northern parts of the quadrangle.
Tertiary sediments are preserved in the hanging wall of the north–south-striking, down-to-the-west Fourth of July normal fault that developed during Tertiary extensional tectonism. The fault cuts fine to coarse fluvial and floodplain sediments of the Cabbage Patch Beds of the Renova Formation (unit Tva). Correlation is based on lithologic similarity with the Cabbage Patch Beds in the adjacent Butte South 30' x 60' quadrangle (McDonald and others 2012), and is supported by the 29.920 ± 0.023 Ma age found for an ash layer at longitude -113.0465 latitude 45.6683 (Roe, 2010). Unsorted pebble to boulder gravel (unit Tcg) overlying the Cabbage Patch Beds resembles the Miocene Sweetwater Member of the Sixmile Creek Formation (Fritz and Sears, 1993), and does not appear to be cut by the Fourth of July Fault, suggesting that it was not active through Miocene time.

The northeast- and northwest-trending high-angle faults with minor displacement that crisscross the quadrangle also probably formed in Late Cretaceous through Tertiary time. Pleistocene glaciers formed at high elevations and advanced northward down the Wise River and Pettengill Creek valleys, leaving extensive deposits of till and glaciofluvial material.

DESCRIPTION OF MAP UNITS

Cenozoic Deposits

Qal **Alluvium (Holocene)**—Gravel, sand, silt, and clay in modern stream channels and floodplains. Thickness less than 30 m (100 ft) thick.

Qta **Talus deposit (Holocene)**—Angular, unsorted to poorly sorted boulders. Mostly pro-talus ramparts, talus aprons, and recent frost-wedged quartzite debris. Thickness less than 18 m (60 ft).

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 deposit (Holocene and Pleistocene)**—Subangular to subrounded, poorly sorted, cobble to boulder gravel, silt, and sand. Thickness probably less than 60 m (200 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 deposits (unit Tva). Thickness probably less than 30 m (100 ft).

Qao **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 10 m (33 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 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).

Tcg **Conglomerate (Miocene?)**—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 and was probably deposited in a system of coalescing alluvial fans and debris flows. Overlies unit Tva in the central part of the map, but age relationships in other areas are indeterminate. Tentatively correlated with the Sweetwater Member of the Sixmile Creek Formation, which is found to the east (McDonald and others, 2012; Fritz and Sears, 1993). Possibly as much as 300 m (1,000 ft) thick.

Tva **Volcanic ash deposit (Oligocene)**—Yellowish clay containing 5–20 percent silt, fine glass shards, tiny biotite flakes, and 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 the fluvial gravels are interbedded with tuffaceous debris flows. Roe dated an ash layer in the quadrangle at 29.920 ± 0.023 Ma. Tentatively correlated with the Cabbage Patch Beds of the Renova Formation. Unit occurs on the downthrown western side of the Fourth of July fault. 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 along the eastern edge of the quadrangle. The Sheep Mountain Fault, shown on cross section A–A', developed at a low angle to bedding and omits various Cambrian units (McDonald and others, 2012; Lonn, 2015).

Pzs **Paleozoic sedimentary rocks, undivided (Paleozoic)**—Sheared and brecciated light gray limestone and dolomite. Occurs as fault slices along the Ross Gulch and Pettengill Faults.

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.

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) (Winston, 1986). Argillite has a lumpy appearance and locally contains trace fossils. Quartzite is white, fine-grained, feldspathic and well sorted. Cqba is equivalent to the Swamp Creek sequence of Zen (1988) and Ruppel and others (1993), and is thought to be equivalent to the Silver Hill Formation. On the east-adjacent Butte South quadrangle (McDonald and others, 2012), the Sheep Mountain Fault is subparallel to bedding and omits stratigraphic section (Lonn, 2015); as a result, thickness is unknown.

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. Lacks the pink and red quartzite and brick-red chert clasts of the Black Lion Formation (unit Ybl). Grains are subrounded to subangular, and moderately to well sorted, although coarse intervals are poorly sorted. Contains abundant well-rounded quartz grains. In hand sample, the fine-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 southeast of the map, where a low-angle unconformity with the underlying Black Lion Formation is clearly visible (McDonald and others, 2012). Appears to grade upward into the quartzite and argillite of unit Cqba at Grace Lake. 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. The only exposure on the Stine Mountain quad is a thin fault sliver in the southeastern part of the quadrangle.

PROTEROZOIC UNITS

Low-grade metasedimentary rocks of Mesoproterozoic age underlie much of the Stine 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 Stine Mountain quadrangle with units of the Lemhi subbasin (Burmester and others, 2013, 2016) that lie stratigraphically above the Lemhi Group (Ruppel, 1975). These units–the Swauger and Lawson Creek Formations–are present in the hanging wall of the Grasshopper Thrust. In the footwall, Mesoproterozoic stratigraphy is represented by the Black Lion Formation, which is thought to be a basin-margin facies deposited along the edge of the Lemhi subbasin.

Ylc **Lawson Creek Formation (Mesoproterozoic)**—Characterized by couplets and couples (Winston, 1986) 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 up to 93 percent of the grains in contrast to the feldspathic Swauger Formation. 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. Tentatively correlated with the McNamara Formation of the Missoula Group, Belt Supergroup (Burmester and others, 2015). Upper contact not exposed on the Stine 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. Some 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-up clasts are common. Rare argillite beds typically contain desiccation cracks. Gritty intervals as much as 5 m thick are lithologically identical to gritty intervals in the Black Lion Formation (Ybl). Both the Swauger and Black Lion Formations contain angular gneissic, granitic, black lithic, and red chert clasts, suggesting that the two interfinger. The lower part of the Swauger Formation only contains potassium feldspar (Calbeck, 1975). The upper part is pink to gray, thick-bedded, medium- to fine-grained quartzite, massive to trough-crossbedded. 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. Plagioclase is everywhere less abundant than potassium feldspar. Equivalent to Zen's (1988) Boner Knob and Maurice Mountain quartzites, to Calbeck's (1975) Belt 1 and 2, and to Lonn and McDonald's (2004b) Bonner Formation. 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 multicolored, subangular to rounded lithic fragments. Typically 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 and pink to white quartzite clasts that are usually rounded; these clasts are rare to absent in the overlying Grace Lake quartzite (unit Cqlg). Contains intervals of light gray, medium-grained, quartz-rich, subangular to subrounded, well-sorted quartzite with abundant coarse round quartz grains. In the Stine Mountain quadrangle, the upper contact of Ybl is the Sheep Mountain Fault, but in the Grace Lake area east of the quadrangle the upper contact is an angular unconformity (McDonald and others, 2012). The lower contact appears to be a nonconformity with the underlying Paleoproterozoic gneiss at Sheep Mountain east 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 is 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. As much as 500 m (1,625 ft) thick (Zen, 1988).

Xga **Gneiss and amphibolite (Paleoproterozoic)**—Foliated plagioclase gneiss, augen gneiss, banded fine-grained and coarse-grained gneiss, and amphibolite. Very rare quartzose, slightly calcareous layers. Interpreted by McDonald and others (2012) as non-conformable with the overlying Proterozoic Black Lion Formation. Foster and others (2006) obtained a 1.86 Ga U-Pb age from dioritic orthogneiss interpreted to represent the protolith's crystallization age. Exposed only in a small area along the eastern edge of the map.

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).

Tqp **Quartz porphyry (Paleocene)**—Rounded 1-cm smoky quartz phenocrysts in a matrix of quartz, feldspar, biotite, euhedral sphene, and apatite (Zen, 1988). Occurs only along the eastern edge of the map.

TKg **Granite of Clifford Creek (Paleocene and/or Late Cretaceous)**—Massive, coarse-grained two-mica granite, locally porphyritic. Porphyritic phase has white euhedral potassium feldspar phenocrysts as much as 3 cm long. K-Ar age of 64.9 ± 2.2 Ma (Pearson and Zen, 1985).

Kg **Granite of Stine Creek (Late Cretaceous)**—Medium-grained, gray biotite granite. Contains rare muscovite and rare secondary epidote and anhedral sphene. Small body near Grouse Lakes is granodiorite containing hornblende, biotite, and euhedral sphene.

Kgp **Porphyritic biotite granite of Osborne Creek (Late Cretaceous)**—Very coarse, porphyritic, biotite granite. Potassium feldspar occurs as pink, euhedral phenocrysts as much as 2 cm across. Found only in the northwest corner of the map.

Kto **Tonalite of Foolhen Mountain (Late Cretaceous)**—Gray, fine- to medium-grained hypidiomorphic granular to porphyritic tonalite and granodiorite containing 10–20 percent biotite and hornblende, and less than 5 percent potassium feldspar (Berger and others, 1983; Truckle, 1988). Occurs only in the northwest corner of the map, but is extensively exposed west of the quadrangle (Berger and others, 1983; Lonn and McDonald, 2004b). Called the Foolhen Mountain tonalite by Snee (1982) and Truckle (1988) and the tonalite of Foolhen Ridge by Berger and others (1983). Snee (1982) proposed an emplacement age of about 77 Ma, with biotite $^{40}Ar/^{39}Ar$ cooling ages decreasing westward within this pluton from 69 to 65 Ma.

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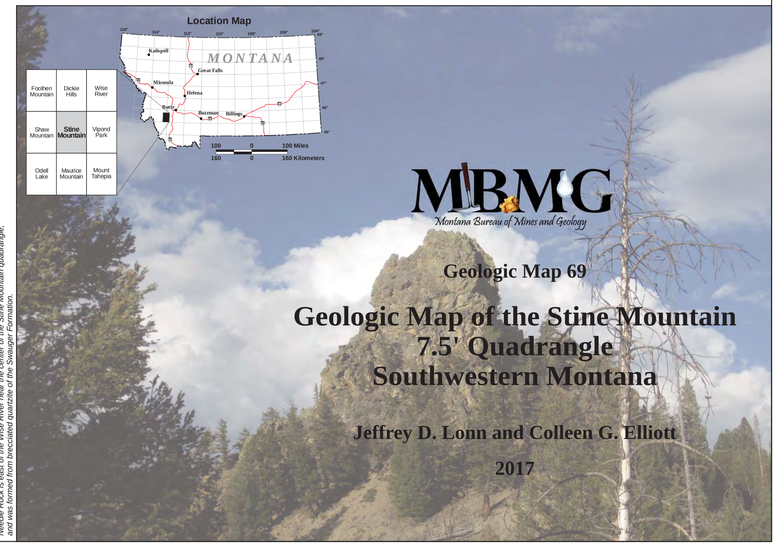

Steeply dipping beds west of the Wise River along the eastern margin of the Stine Mountain quadrangle, and Miocene to Recent fluvial deposits west of the Sheep Mountain Fault.