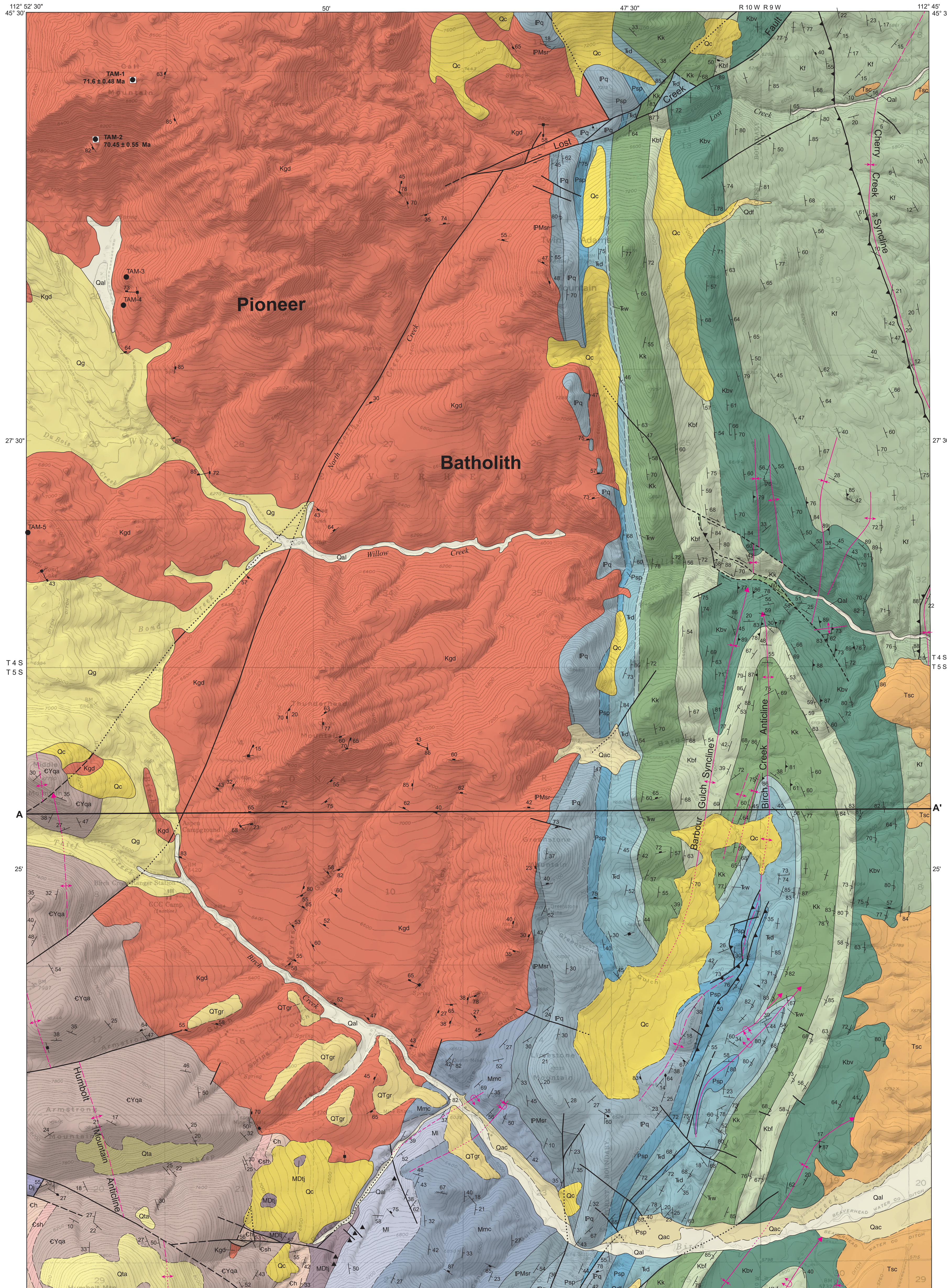


Base map produced by the United States Geological Survey
Twin Adams Mountain 1:24,000-scale quadrangle map
Control by: USGS and NOS/NOAA
Compiled from aerial photographs taken 1950
Field checked: 1952
Projection: Polyconic
Grid: 1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 1°18' West
1988 Magnetic North Declination: 16.5° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

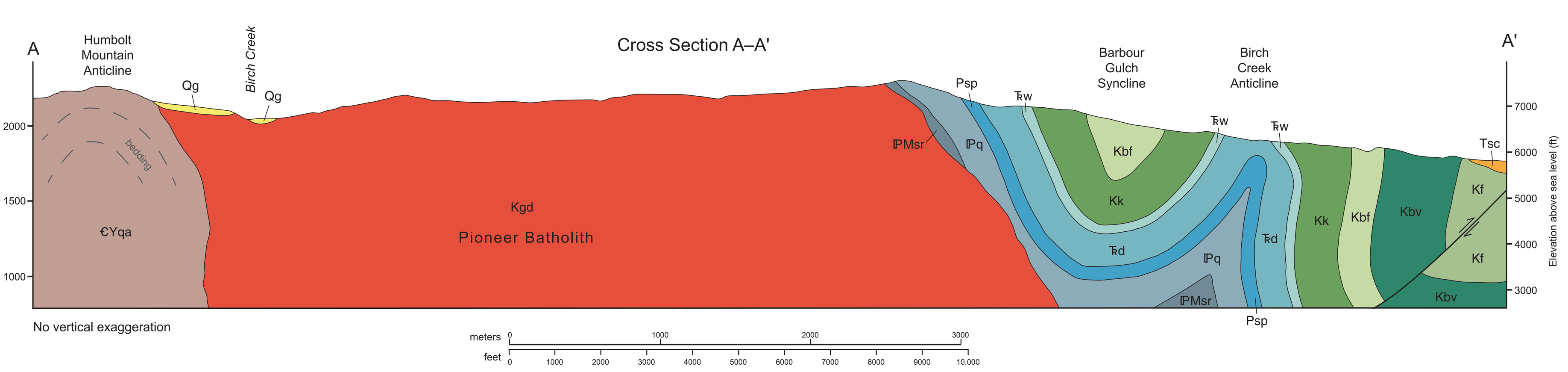
Shaded relief created from 10 meter digital elevation model from U.S. Geological Survey National Elevation Dataset.

SCALE 1:24,000

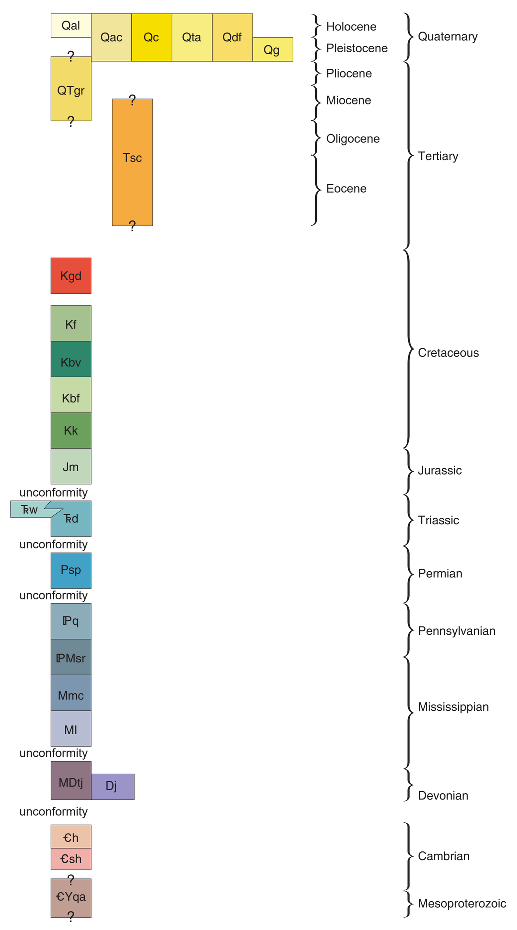
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4174
http://mbmg.mtech.edu

Cross Section A–A'



CORRELATION DIAGRAM



MAP SYMBOLS

Contact: dashed where approximately located

Fault: dashed where approximately located; dotted where concealed, bar and ball on downthrown side; arrows show dip value and direction

Reverse or thrust fault: dashed where approximately located; dotted where concealed, teeth on upthrown block

Anticline: dashed where approximately located; dotted where concealed; arrow indicates plunge

Syncline: dashed where approximately located; dotted where concealed; arrow indicates plunge

Overturned anticline: dashed where approximately located; dotted where concealed; arrow indicates plunge

Overturned syncline: dashed where approximately located; dotted where concealed; arrow indicates plunge

35 Strike and dip of inclined beds

84 Strike and dip of overturned bedding

Strike of vertical bedding

73 Strike and dip of cleavage

87 Strike and dip of metamorphic foliation

73 Strike and dip of joints

Strike of vertical joints

45 78 Strike and dip of joints, multiple observations at same location

71.6 ± 0.48 U-Pb zircon radiometric age data sample point with age in Ma

TAM-1 Geochemical sample point with sample number

Tectonic breccia

Table 1. Bulk rock geochemical data from samples collected in the Twin Adams Mountain 7.5' quadrangle.

Sample ID	TAM-1	TAM-2	TAM-3	TAM-4	TAM-5
Map unit	Kgd	Kgd	Kgd	Kgd	Kgd
Latitude	45.493	45.488	45.474	45.471	45.449
Longitude	-112.861	-112.866	-112.862	-112.862	-112.876
Major elements (wt %)					
SiO_2	66.03	67.00	68.40	68.91	69.57
TiO_2	0.42	0.36	0.30	0.27	0.30
Al_2O_3	16.01	15.79	15.87	15.68	15.15
FeO*	3.99	3.42	2.80	2.44	2.71
MnO	0.10	0.08	0.07	0.08	0.08
MgO	1.34	1.23	0.90	0.81	0.89
CaO	4.30	3.88	3.48	3.28	2.77
Na_2O	3.40	3.78	3.47	3.42	3.25
K_2O	2.85	2.92	3.28	3.54	3.89
P_2O_5	0.15	0.13	0.12	0.10	0.09
Sum	98.59	98.60	98.68	98.54	98.70
LOI	0.57	0.48	0.47	0.60	0.38
Trace elements (ppm)					
Ni	3.2	3.8	4.1	3.3	3.4
Cr	4.4	5.4	4.0	3.9	2.8
V	58.5	50.5	38.7	34.7	40.9
Ga	19.2	18.6	18.7	19.0	17.5
Cu	2.8	5.7	2.1	9.8	1.3
Zn	59.9	54.6	50.5	52.3	57.7
La	32.6	31.1	29.5	32.0	24.6
Ce	59.9	58.0	54.2	58.7	46.3
Pr	6.6	6.4	6.1	6.5	5.2
Nd	24.2	23.1	22.0	23.3	18.3
Sm	4.3	4.3	4.2	4.3	3.5
Eu	1.2	1.2	1.2	1.2	0.9
Gd	3.6	3.5	3.3	3.4	3.0
Tb	0.6	0.5	0.5	0.5	0.5
Dy	3.3	3.2	2.9	3.1	3.2
Ho	0.7	0.6	0.6	0.6	0.7
Er	1.9	1.7	1.7	1.7	2.0
Tm	0.3	0.3	0.3	0.3	0.3
Yb	1.8	1.8	1.7	1.6	2.1
Lu	0.3	0.3	0.3	0.3	0.4
Ba	1145.9	947.0	1448.9	1556.8	975.9
Th	7.9	8.1	7.0	8.2	10.8
Nb	11.8	12.7	14.0	13.4	16.8
Y	18.5	17.6	16.5	16.2	18.4
Hf	4.8	4.7	4.6	4.4	3.8
Ta	0.8	0.9	1.0	0.9	1.7
U	2.1	1.7	1.9	2.0	2.5
Pb	16.2	18.0	19.9	20.6	24.8
Rb	85.6	91.4	102.1	100.0	127.8
Cs	2.2	2.4	1.6	1.7	3.3
Sr	544.3	535.8	546.6	541.4	361.8
Sc	7.7	6.4	5.2	4.3	5.5
Zr	186.7	177.3	165.4	160.4	130.6

All samples analyzed by X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) at the Washington State University GeoAnalytical Lab. FeO* indicates all Fe expressed as Fe^{2+}. LOI is loss on ignition.

Table 2. New U-Pb zircon age data

Sample	Map Unit	Latitude	Longitude	Age (Ma)	2σ (Ma)
TAM-1	Kgd	45.493	-112.861	71.60	0.48
TAM-2	Kgd	45.488	-112.866	70.45	0.55

Samples analyzed by LA-ICP-MS at the University of California, Santa Barbara. Datum for sample coordinates is 1983 North American Datum (NAD83).

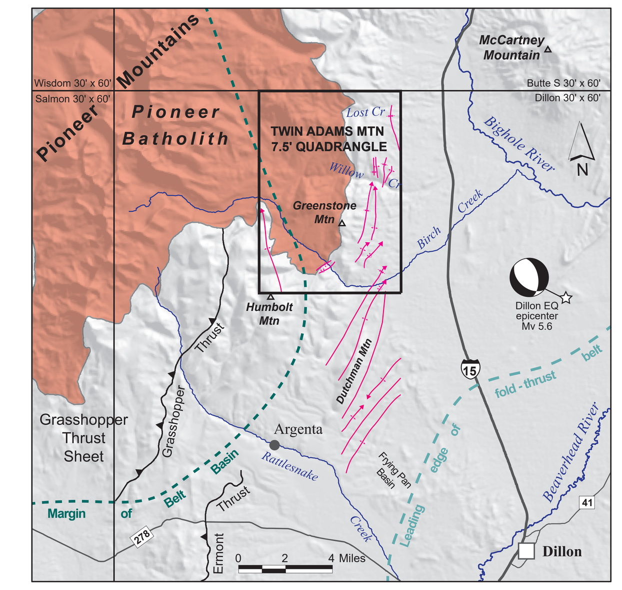


Figure 1. Simplified tectonic map of the area surrounding the Twin Adams Mountain 7.5' quadrangle.

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG), in conjunction with the STATEMAP advisory committee, selected the Twin Adams Mountain 7.5' quadrangle in southwest Montana for detailed mapping as part of the MBMG's on going effort to complete the Dillon 30' x 60' (1:100,000 scale) geologic map. The Twin Adams Mountain 7.5' quadrangle is located northwest of Dillon, Montana along the southeastern margin of the Pioneer Mountains (fig. 1). A key goal of the mapping was to reevaluate the Cambrian and Mesoproterozoic rocks in the southwest part of the quadrangle using new stratigraphic interpretations developed by MBMG and Idaho Geologic Survey geologists in the west-adjacent Salmon 30' x 60' quadrangle (Lonn and others, in review).

PREVIOUS MAPPING

The Twin Adams Mountain 7.5' quadrangle is included in small-scale mapping by Ruppel and others (1993, scale 1:250,000) and larger-scale mapping by Myers (1952, scale 1:31,680), Sharp (1970, scale 1:24,000), Peters (1971, scale 1:24,000), and Tysdal and others (1994, scale 1:24,000). The extent of the previous mapping is shown in figure 2.

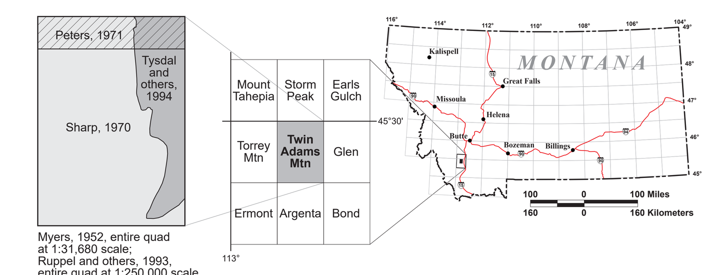


Figure 2. Previous mapping and location map.

GEOLOGIC SUMMARY

The eastern and southern parts of the Twin Adams Mountain quadrangle are underlain by a thick sequence of Mesoproterozoic to Cretaceous strata. Most of the western part of the quadrangle is underlain by the Late Cretaceous Pioneer Batholith. Many of the base metal mines of the historic Birch Creek (Utopia) mining district (Geach, 1972) are within the Twin Adams Mountain quadrangle. These mines are mostly skarn deposits localized along the contact between the Pioneer Batholith and Mississippian and Pennsylvanian carbonate rocks.

The oldest rocks in the quadrangle are Mesoproterozoic (?) to Cambrian quartzites and argillites exposed along the Humbolt Mountain Anticline in the southwest corner of the map. These rocks were previously mapped as part of the Missoula Group of the Mesoproterozoic Belt Supergroup (Myers, 1952; Ruppel and others, 1993). However, part of the section, characterized by thin beds of dark green to black argillite interbedded with thicker beds of medium- to coarse-grained quartzite, is interpreted as Cambrian based on the discovery of trace fossils in float at the top of Humbolt Mountain. The age of the underlying strata, which consists of quartzites lacking feldspar and underlying interbedded feldspar-poor quartzites and argillites, is interpreted as Cambrian and possibly Mesoproterozoic. The quartzites in this older strata are typically reddish, finer grained, and thinner bedded than the overlying Cambrian strata. The contact between the Cambrian and Mesoproterozoic rocks is poorly exposed, and for mapping purposes, the units were not subdivided.

Devonian through Cretaceous rocks are well exposed in a series of northwest- to northeast-trending folds in the eastern half of the quadrangle. The Devonian through Mississippian rocks are predominately marine carbonates that unconformably overlie Cambrian dolomite. They are overlain by Late Mississippian to Early Triassic strata that record the transition from dominantly carbonate deposition to marginal marine and continental siliciclastic deposition. Rocks of Middle Triassic through early Late Jurassic are missing in southwest Montana. Their absence reflects a fundamental change in the tectonic setting of western North America from a relatively stable shelf setting to an actively subsiding foreland basin setting (Gibson, 2007). Continental foreland basin deposits in the quadrangle include the Triassic Woodside Formation, the Late Jurassic Morrison Formation, and overlying Early Cretaceous Kootenai Formation. The Early to Late Cretaceous Blackleaf and Frontier Formations record the return of marine deposition to the area.

Igneous intrusive rocks of the Late Cretaceous Pioneer Batholith intrude Mesoproterozoic through Permian rocks. The intrusive rocks range in composition from granodiorite to granite (table 1). North of the quadrangle, this part of the batholith was mapped by Zen (1988) as the Uphill Creek Pluton, the largest of five plutons that form the Pioneer Batholith. New U-Pb zircon ages of 70.45 ± 0.55 Ma and 71.60 ± 0.48 Ma (table 2) obtained during this mapping are within the range of ages summarized by Zen (1988) for the pluton. Contact metamorphism along the steep, generally concordant eastern and southern contact created numerous garnet-epidote skarns that produced copper, lead, silver, and gold (Geach, 1972). The contact aureole extends up to 2 km (1.6 mi) and is characterized by marble and hornfels.

The youngest deposits in the quadrangle are Tertiary and Quaternary surficial deposits. Tertiary debris-flow and fluvial deposits consist of fine-grained sands, gravels, and conglomerates exposed along the eastern edge of the map. These deposits may correlate with the Miocene Sixmile Creek Formation. The most widespread Quaternary deposit is Pleistocene glacial till (Thomas and others, 2007) that forms lateral and terminal moraines along Willow, Birch, and Thief Creeks. Other surficial deposits include alluvium along modern streams, and colluvium and debris flows that occur on steeper slopes throughout the quadrangle.

STRUCTURE

The structurally complex Twin Adams Mountain quadrangle is within the leading edge of the Sevier–Laramide fold-thrust belt. Structural features record both crustal thickening and shortening within the fold-thrust belt and Tertiary Basin and Range extension. Shortening structures are considered broadly synchronous with Late Cretaceous emplacement of the Pioneer Batholith (Kalakay and others, 2001).

Paleozoic to Mesozoic strata in the quadrangle likely underwent three phases of shortening, which formed (1) NNW- to ENE-trending major and minor folds (fig. 3) and faults, (2) east–west-trending minor folds, and (3) a steep north–south-striking cleavage. The NNW- to ENE-trending folds and thrusts are the most prominent structures associated with shortening. The NNW-trending Humbolt Mountain Anticline (Myers, 1952) exposes Mesoproterozoic and Cambrian strata. The Birch Creek Anticline and Barbour Gulch Syncline (Sharp, 1970) deform Mississippian through Cretaceous strata; the Cherry Creek Syncline deforms the Cretaceous Frontier Formation. The Cherry Creek Syncline is a prominent regional feature locally faulted along and across its axial trace (Tysdal and others, 1994). It has been mapped and discussed by various workers including Tysdal and others (1994), Zen (1988), Brandon (1984), and Peters (1971). The trace of the axial plane of this fold generally parallels the most prominent thrust fault in the quadrangle and the fold is likely a footwall syncline contemporaneous with thrusting (Tysdal and others, 1994).

Numerous minor folds and thrust faults are also present in the quadrangle, especially in the thinner bedded parts of the Dinwoody and Kootenai formations. The traces of the minor folds and faults generally parallel those of the larger structures. Locally, the major and minor folds are overturned to the east and most plunge to the north. However, a small number of minor folds are open, upright, and trend east–west, suggesting this region underwent minor north–south shortening after the formation of the major northwest- to northeast-trending structures. A well-developed cleavage in Cretaceous strata strikes north–south and dips steeply (80°–90°, fig. 4), in contrast to the axial planes of major folds which dip towards the west at shallower angles (~68°). This mismatch between cleavage and axial plane orientations suggests that Mesozoic strata underwent a second generation of east–west shortening after the development of major folds and faults.

The youngest structures in the quadrangle are steep, northwest- and northeast-trending faults that offset the older structures. Rare, poorly exposed fault surfaces indicate both dip-slip and strike-slip motion. The prominent faults of this type are the right-lateral Lost Creek Fault (Tysdal and others, 1994), the fault zone to the south along Willow Creek also showing right-lateral displacement, and the unnamed fault along North Creek. The age of the extensional faults is uncertain but they offset the Late Cretaceous Pioneer Batholith and may be associated with regional Tertiary extension in southwest Montana.

Quaternary faults have not been recognized in the Twin Adams Mountain quadrangle, but the epicenter of the 2005 Mw 5.6 Dillon earthquake was located approximately 12 km (7 mi) east of the quadrangle (fig. 1). The earthquake appears to have originated on a north- to northwest-trending, east-dipping normal fault in a region lacking identified Quaternary faults (Stickney, 2007).

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated, poorly sorted deposits of gravel, sand, silt, and clay deposited by modern streams. Cobbles and boulders generally subrounded to well-rounded and consisting predominantly of quartzite and granodiorite. Thickness as much as 10 m (33 ft).

Qac **Alluvium and colluvium (Holocene and Pleistocene?)**—Unconsolidated sand, silt, clay, and subordinate gravel, deposited on gentle slopes by sheetwash and as alluvium along minor streams. Thickness generally less than 10 m (33 ft).

Qc **Colluvium (Holocene and Pleistocene?)**—Unconsolidated, locally derived slope deposits that contain angular, poorly size-sorted clasts, generally with clasts that are pebble size and larger. Thickness generally less than 10 m (33 ft).

Qta **Talus deposit (Holocene and Pleistocene)**—Unconsolidated, locally derived, apron-like deposit with angular clasts on and below steep slopes. Includes some rock-slide deposits. Variable thickness, generally less than 10 m (33 ft).

Qdf **Debris-flow deposit (Holocene)**—Angular, subangular, and subrounded clasts of chaotic and unstratified boulders and cobbles, and subordinate finer sediment. Some fine sediment was probably removed by erosion, leaving coarser clasts as lag deposits. Estimated maximum thickness of 15 m (50 ft) thick.

Qg **Glacial deposit (Pleistocene)**—Weakly stratified deposit of clay, silt, sand, and gravel with abundant, locally derived, rounded to sub-rounded cobbles and boulders. Granite and quartzite clasts are most abundant; argillite, hornfels, limestone, and sandstone are less abundant. Thickness estimated to be up to 100 m (330 ft).

QTgr **Gravel and conglomerate deposit (Miocene? and Pleistocene)**—Unconsolidated, poorly sorted, massive to crudely bedded, gravel and conglomerate deposits in a matrix of sand, silt, and clay. Clasts are subangular to subrounded cobbles and boulders [some up to 0.6 m (2 ft) in diameter] consisting mostly of quartzite but also sandstone, argillite, limestone, chert, and granitic rock. May be glacial lags or lags equivalent to the Miocene Sweetwater Creek member of the Sixmile Creek Formation, which has been interpreted as debris-flow deposits on alluvial fans (Fritz and Sears, 1993). Mapped on south side of Birch Creek in western part of map where the gravels rest on bedrock. Thickness probably less than 12 m (40 ft).

Tsc **Sixmile Creek Formation (Miocene)**—Heterogeneous, unconsolidated deposits ranging from poorly stratified, light brown clay to silty sand with rare tuff and lithic fragments to light to reddish brown matrix supported conglomerate, with clay to silt matrix, and poorly sorted angular coarse sandstone to pebble clasts. Clasts are composed of quartzite, chert, sandstone, and siltstone, likely representing local sourcing of Paleozoic and Mesozoic strata. North of Birch Creek may correlate with the Sweetwater Creek member of the Sixmile Creek Formation, which has been interpreted as a debris-flow deposit (Fritz and Sears, 1993). South of Birch Creek may correlate with the Big Hole member of the Sixmile Creek Formation, which has been interpreted as a fluvial deposit (Fritz and Sears, 1993). Base not exposed but about 30–45 m (100–150 ft) thick.

Kgd **Granodiorite (Late Cretaceous)**—Light to medium gray, equigranular, coarse-grained, granodiorite and granite (66.03–67.55 wt. percent SiO_2; table 1). Hornblende and biotite are the dominant mafic minerals. Jointing is conspicuous and commonly at 1–2 m spacing. This unit is part of the Uphill Creek Pluton of the Pioneer Batholith (Zen, 1988; Snee, 1978, 1982) and yielded two U-Pb zircon ages of 70.45 ± 0.55 Ma and 71.60 ± 0.48 Ma (table 2).

Kf **Frontier Formation (Late Cretaceous)**—Dominantly gray, brown, brownish gray, and greenish gray siltstone and mudstone, and subordinate medium- to coarse-grained, and locally very coarse-grained sandstone, conglomerate, limestone, and minor porcellanite. The beds of mudstone, siltstone, limestone, and sandstone form fining-upward depositional cycles tens of meters thick. Sandstone and conglomerate are rich in quartz and chert. Conglomerate clasts are rounded pebbles and small cobbles. Volcaniclastic sandstone and bentonitic mudstone occur in upper part. Lower 100–200 m (330–660 ft) is distinctive brown to brownish gray siltstone and mudstone. Top not exposed but thickness about 900 m (3,000 ft) north of the quadrangle (Tysdal and others, 1994; Dyman and Nichols, 1988).

Kbv **Blackleaf Formation, Vaughn Member (Early to Late Cretaceous)**—Olive green, yellowish green, bright green, and gray green, hard, dense, and calcareous siltstone and porcellanitic (silicified) mudstone. Subordinate gray, greenish gray and olive gray, fine- to medium-grained, and locally coarse-grained lithic sandstone, with high percentage of volcaniclastic debris, and matrix-supported conglomerate and conglomeratic sandstone with clasts mostly of chert and quartzite. An association of distinctive lithologies is present in the uppermost part, which consists of maroon mudstone and siltstone, gray freshwater limestone or locally, very calcareous mudstone and siltstone, dark gray shale, and bright green porcellanite. Upper contact is mapped at top of a porcellanite bed, interbedded with micritic limestone that directly overlies the highest maroon mudstone (Tysdal and others, 1994; Dyman and Tysdal, 1998). A porcellanite bed approximately 25 m (80 ft) below the top of the Vaughn in the Frying Pan Basin (in the south adjacent Argenta 7.5' quadrangle) yielded a U-Pb age of 94.8 ± 0.5 Ma (Zartman and others, 1995). Thickness approximately 488 m (1,600 ft) ; (Tysdal and others, 1994).

Kbf **Blackleaf Formation, Flood Member (Early Cretaceous)**—
Upper part: Pale brown to brownish gray, fine- to medium-grained and locally coarse-grained to conglomeratic, quartz- and chert-rich lithic sandstone and conglomerate. Trough crossbedding common in sandstone.
Middle part: Dominantly gray mudstone, shale, and minor interbeds of siltstone and quartz-rich sandstone.
Lower part: Medium gray and locally green and red calcareous siltstone and mudstone, gray shale, and gray, calcareous, fine- to medium-grained sandstone that is rich in quartz and chert grains (Tysdal and others, 1994; Dyman and Nichols, 1988).
Total thickness of Flood Member is about 213 m (700 ft).

Kk **Kootenai Formation (Early Cretaceous)**—Mapped as one unit, but consists of four distinct units (after Myers, 1952). Combined thickness of all units about 290 m (950 ft).
Gastropod limestone member: Light gray, thick-bedded, gastropod coquina or gastropod-rich limestone that may also contain charophytes and ostrocodes. Forms conspicuous ridges at the top of the formation.
Red mudstone member: Variegated shale and mudstone, dominated by red, orange, and purple, and subordinate light and medium gray colors, interbedded with minor reddish quartz- and chert-rich lithic sandstone. Poorly exposed, recessive unit.
Fine-grained limestone member: Pale yellowish gray to pale brown, dense limestone and shaley limestone with interbedded shale.
Basal sandstone and mudstone: Upper part recessive, mostly reddish and greenish mudstone; lower part is ridge-forming, coarse- to medium-grained, cross-bedded to massive, brown to yellowish gray, chert-rich lithic sandstone with local lenses of chert-rich conglomerate and limestone pebble conglomerate; interbedded with reddish and greenish mudstone.

Jm **Morrison Formation (Late Jurassic)**—Pale green, olive green, red, and gray variegated mudstone, shale, and siltstone with thin, interbedded yellowish brown to grayish orange, very fine-grained sandstone, siltstone, and gray limestone. North of Birch Creek the Morrison is either absent or very thin due to pre-Kootenai Formation erosion. Thickness: 0–55 m (0–175 ft).

Ʀw **Woodside Formation (Early Triassic)**—Dark to pale red, calcareous mudstone and siltstone with subordinate gray limestone and fine-grained, thin-bedded sandstone with ripple laminae. Includes minor matrix-supported conglomerate in laterally discontinuous beds up to 0.3 m (1 ft) thick. Conglomerate clasts are subangular to subrounded sandstone, shale, and limestone. Locally the conglomerate is red sandstone with white quartzite cobbles. Best exposures are north of Birch Creek; south of Birch Creek it is thin or absent, presumably due to non-deposition. Myers (1952) mapped this interval as entirely Woodside but the upper part, where sandstone and limestone are more common, may be the Thaynes Formation (MacLachlan, 1972). Thickness up to about 60 m (200 feet).

Ʀd **Dinwoody Formation (Early Triassic)**—Interbedded shale, limestone, and calcareous sandstone characterized by platy, thinly laminated beds that weather a distinctive pale to light grayish brown. Upper part has massive calcareous, rippled sandstone beds as much as 1 m (3 ft) thick with shaley interbeds and massive, gray, pinkish gray weathering, limestone as much as 1 m (3 ft) thick. Phosphatic pelecypod Lingula and fish bone fossils are locally abundant. Lower part is predominantly olive drab, chippy-weathering, hard fissile shale with interbedded dark brown weathering, silty limestone beds 10 cm (4 in) or thinner. Thickness about 200 m (650 ft).

Psp **Shedhorn and Phosphoria Formations, undivided (Permian)**—Shedhorn Formation is grayish brown, fine-grained, thin- to thick-bedded quartz sandstone, and cherty sandstone with chert and quartz cement. Vertical and horizontal burrows are common. Phosphoria Formation is dark gray to black, carbonaceous and phosphatic mudstone with scarce phosphate beds, grayish and gray brown cherty quartz sandstone, cherty or sandy dolomite, fine-grained dolomitic sandstone, and yellowish tan sandy siltstone with subordinate beds of vitreous quartz sandstone. Poorly exposed, typically covered by colluvium and talus of underlying Quadrant Formation. Thickness approximately 89 m (300 ft).

IPq **Quadrant Formation (Pennsylvanian)**—Light gray to light yellowish brown, fine-grained, vitreous, quartz sandstone and quartzite. Beds are mostly thick to massive, occasionally with faint cross-laminations. Locally, the basal quartz sandstone beds are interbedded with thin intervals of limestone or dolomite and locally have gray limestone rip-up clasts. Forms resistant ridges typically covered with conifers. Outcrops are locally fractured and brecciated. Thickness approximately 198 m (650 ft).

IPMsr **Snowcrest Range Group (Pennsylvanian and Late Mississippian)**—Formerly mapped as Amsden Formation in this area (Myers, 1952) but now mapped as the Snowcrest Range Group, which contains the Conover Ranch, Lombard, and Kibbey Formations (Wardlaw and Pecora, 1985). Occurs as discontinuous exposures of marble and hornfels along the contact with granodiorite (map unit Kgd) of Pioneer Batholith. Best exposures are south of Greenstone Mountain (sec. 11, T. 5 S., R. 10 W.; fig. 1) where this unit is approximately 61 m (200 ft) thick.

Mmc **Mission Canyon Formation (Mississippian)**—Light gray, thick-bedded, fossiliferous, often cliff-forming limestone with irregular chert bands. Myers (1952) mapped the Mission Canyon as two units that were combined for this map. The upper part is light to dark gray, commonly well-bedded, fine- to medium-grained, with rare coarse-grained beds of crinoidal debris, and minor light to dark gray, thin-bedded dolomitic, locally sandy or cherty limestone. The lower part is generally a coarser grained limestone with abundant crinoids and some intervals of thin-bedded limestone and dolomitic limestone. Becomes coarsely crystalline marble near intrusions. Thickness variable as a result of deformation but estimated to be about 360 m (1,375 ft) thick.

Ml **Lodgepole Formation (Mississippian)**—Gray to dark gray, thin- to medium-bedded, fossiliferous limestone. Thinner beds and shaly partings are common near base, beds are thicker with rare shaley partings near the top. Common fossils are corals and crinoids; brachiopods are rare. The Lodgepole Formation appears to have less chert here than in areas of Montana to the north and east. Becomes coarsely crystalline marble near intrusions. Thickness variable as a result of deformation but generally about 290 m (950 ft) thick.

MDtj **Three Forks and Jefferson Formations, undivided (Mississippian and Devonian)**
Three Forks Formation (Mississippian and Devonian)—Brown, argillaceous, fossiliferous limestone interlayered with black to dark gray, carbonaceous shale, grayish green shale, and light tan, silty sandstone. Forms recessive interval and mapped on the basis of float. Metamorphosed to hornfels near intrusions. Thickness approximately 75 m (250 ft).

Dj **Jefferson Formation (Devonian)**—Upper part is a yellowish weathered solution breccia of fine-grained calcite marble. Lower part is dark gray, coarsely crystalline, weakly mottled dolomite, thin- to thick-bedded, with strong petroliferous odor on fresh surfaces. Thickness approximately 200 m (650 ft).

Ch **Hasmark Formation (Cambrian)**—Light gray to pale yellowish brown, thin- to thick-bedded, medium crystalline dolomite with minor magnesium limestone intervals. Basal part contains common peloids, succeeded upward by oolitic and pisolitic intervals, algal-mat carbonate, and minor intraformational conglomerate and thin quartz sandstone beds. Weathers very light gray with a gritty, laminated surface. Metamorphosed to marble near contact with intrusion (map unit Kgd). Exposed thickness about 122 m (400 ft).

Csh **Silver Hill Formation (Cambrian)**—Poorly exposed, thin-bedded, dark gray to dark grayish red argillite interbedded with medium- to coarse-grained lenses of reddish quartzite. Trace fossils and mica are visible on bedding surfaces. Mapped on the basis of float in southwest corner of map, along margins of the Humbolt Mountain Anticline, where unit is in contact with dolomite of the overlying Hasmark Formation. Locally metamorphosed to hornfels. Thickness not determined but as much as 60 m (200 ft) thick in the southern Pioneer Mountains and locally absent as a result of erosion (Myers, 1952).

CAMBRIAN AND MESOPROTEROZOIC ARGILLITE AND QUARTZITE

Undivided Cambrian to possibly Mesoproterozoic argillites and feldspar-poor quartzites are exposed in the core of the Humbolt Mountain Anticline in the southwest corner of the map. The age of the undivided unit is as young as Cambrian based on the occurrence of well-preserved Cambrian trace fossils in argillite float that is most common in a narrow band at the top of Humbolt Mountain (sec 29, T. 5 S., R. 10 W.). The unit was undivided because it occurs mostly as talus but probably includes strata that correlate with the Flathead and Silver Hill Formations, and perhaps older Neoproterozoic to Mesoproterozoic strata. Blocks of quartzite breccia are common along the slopes around Humbolt Mountain, suggesting there may be unrecognized faults in that area and that the structure is more complex than shown on the map. Three general lithologic intervals can be recognized and are described below; their combined thickness is estimated at about 90 m (300 ft).

CYqa **Quartzite and argillite (Cambrian and Mesoproterozoic?)**—
Upper part (Cambrian): Dark gray, grayish green, and dark grayish red, dense, laminated argillite interbedded with fine- to coarse-grained, gray to pale reddish quartzite. Ripple marks and mudcracks are common bedding structures; lenses of subround to angular pebbles are less common. Well-preserved trace fossils, including *Cruziana, Rusophycus, Paleophycus, Planolites, Skolithos,* and other horizontal and vertical burrows, are present in float, especially at the top of Humbolt Mountain. This unit may correlate with the Silver Hill Formation.
Middle part (Cambrian?): Light gray to grayish orange pink, fine- to medium-grained, feldspar-poor quartzite. Grains are subrounded to rounded with rare (<1–2 percent) dark grains and rare (<5 percent), coarse, well-rounded quartz grains and small quartz and quartzite pebbles. Typically occurs as blocky talus and rubble but isolated outcrops are medium- to thick-bedded, with cross-bedding and, locally, with thin layers of interbedded argillite. This unit may correlate with the Flathead Formation. Best exposures are along the ridge west of Armstrong Mountain (NW corner sec. 26, T. 5 S., R. 10 W.).
Lower part (Mesoproterozoic?): Dark gray to grayish green, laminated argillite interbedded with grayish red to pale reddish, fine- to medium-grained, feldspar-poor quartzite. Argillite beds are typically 2–5 cm (1–2 in) thick and cap the quartzite beds. Quartzite beds range in thickness from 5 cm to about 1 m (2 in to 3 ft). Common sedimentary structures include ripples, cross-bedding, and less commonly, distorted bedding, and mudchips. Best exposures are on lower slopes of Middle Mountain (sec. 8, T. 5 S., R. 10 W.) and in the Sheep Creek drainage.

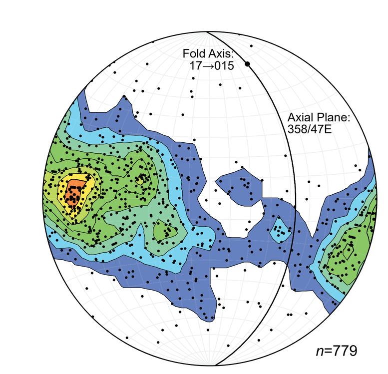


Figure 3. Lower hemisphere projection of poles to bedding measured from Mesoproterozoic through Late Cretaceous strata. Data are plotted on an equal-area stereonet fit with a 2 sigma Kamb contour.

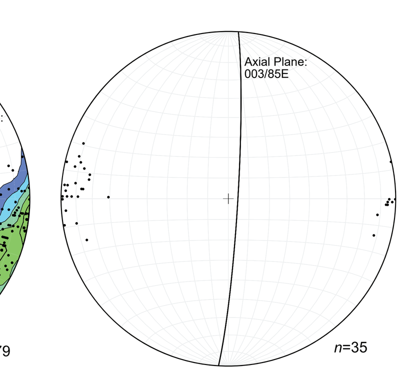


Figure 4. Lower hemisphere projection of poles to cleavage measured from Pennsylvania to Late Cretaceous strata. Data are plotted on an equal-area stereonet.

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Montana Bureau of Mines and Geology

Geologic Map 73

Geologic Map of the Twin Adams Mountain 7.5' Quadrangle, Southwestern Montana

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