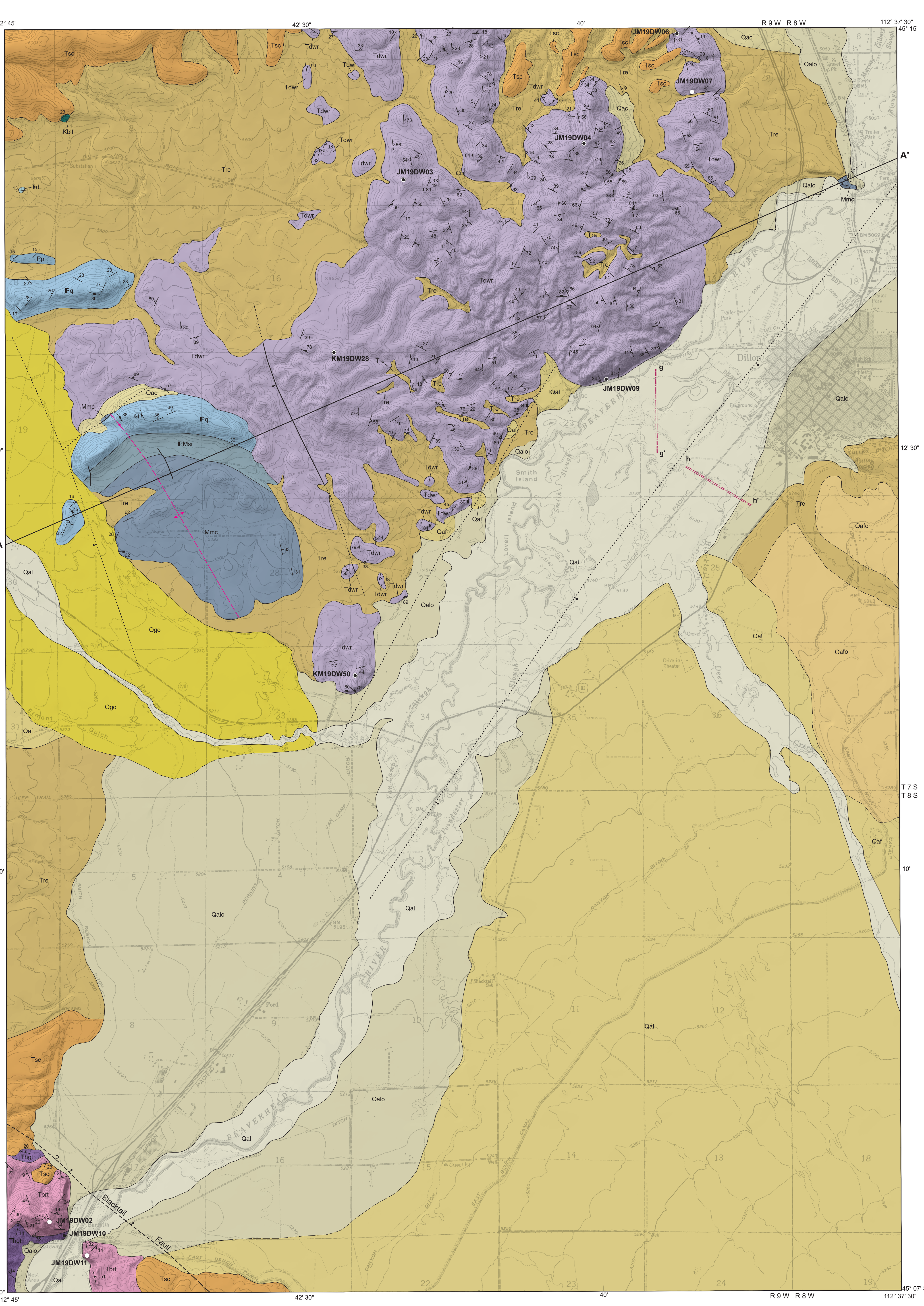
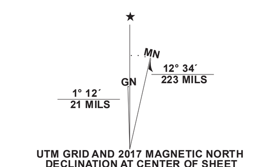


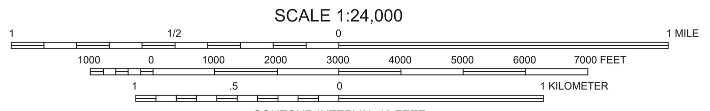
Dillon West 1:24,000-scale quadrangle map
Base map produced by the United States Geological Survey
Control by: USGS and USC&GS
Topography by photogrammetric methods from aerial photographs taken 1960. Field checked 1963
Revisions compiled from aerial photographs taken 1976 and other source data. Not field checked. Map edited 1979
Projection: polyconic
Grid:1000 meter Universal Transverse Mercator Zone 12
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.

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

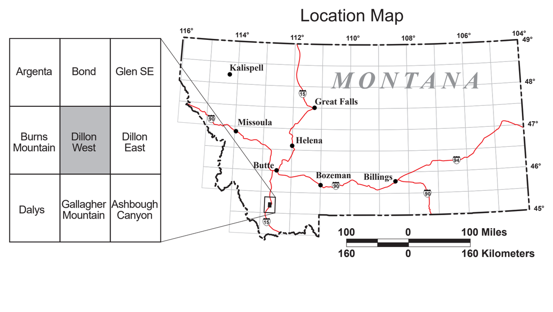


SCALE 1:24,000



CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Location Map



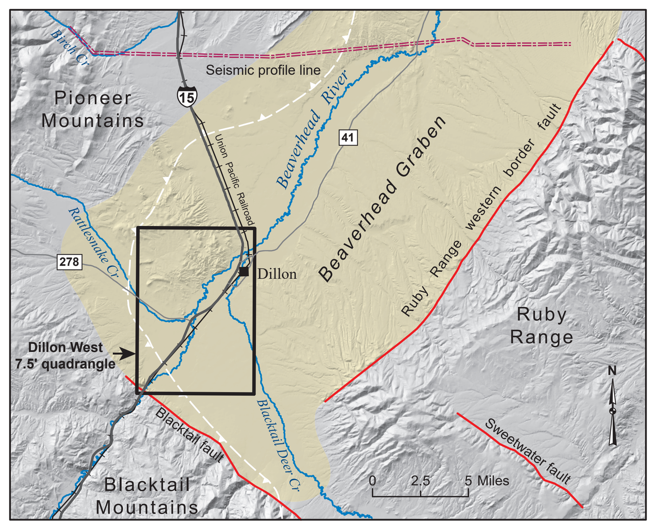
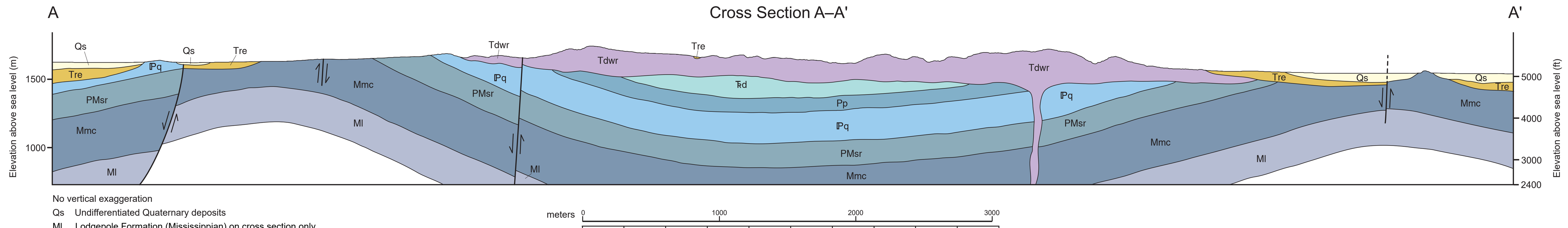


Figure 1. Location map of the Dillon West area. Tectonic features shown are the Beaverhead graben (tan shaded area), the leading edge of the fold–thrust belt (white line with triangles) and identified Quaternary faults (red lines). Quaternary faults from the U.S. Geological Survey and MBMG fault and fold database (accessed 9/04/2022).

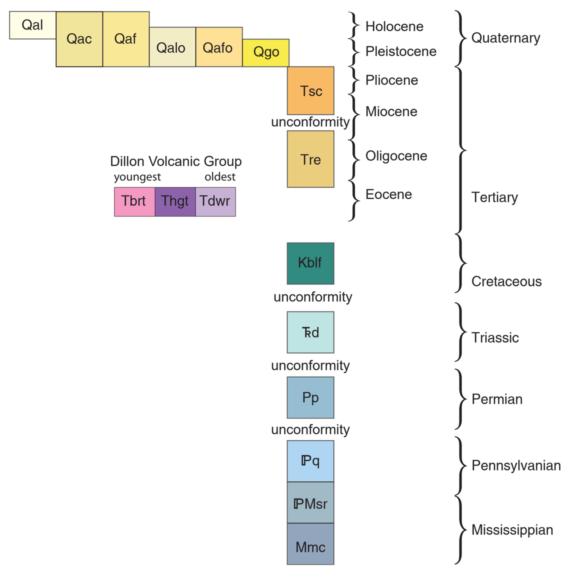
Cross Section A–A′



No vertical exaggeration
Qs Undifferentiated Quaternary deposits
Ml Lodgepole Formation (Mississippian) on cross section only

meters 0 1000 2000 3000
feet 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10,000
SCALE: 1:24,000

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; question mark where inferred; bar and ball on downthrown side
- Anticline, arrowhead shows direction of plunge; approximately located
- 77 Small, minor, inclined joint, showing strike and dip
- 13 Inclined bedding, showing strike and dip
- 30 Gently inclined (between 0° and 30°) bedding from aerial photographs, showing strike and dip
- 74 Inclined igneous foliation, showing strike and dip
- KM19DW50 Geochronology sample location
- KM19DW50 Geochemistry sample location
- Seismic profile line

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG), in conjunction with the State Mapping Advisory Committee, selected the Dillon West 7.5′ quadrangle in southwest Montana for detailed mapping as part of MBMG's on going effort to complete the Dillon 30′ x 60′ (1:100,000-scale) geologic map. The quadrangle is within the upper Beaverhead Valley, which is bordered by the Ruby Range to the east and the Blacktail and Pioneer Mountains to the south and west, respectively (fig. 1). The quadrangle is transected by the north-flowing Beaverhead River and its tributary streams Blacktail Deer and Rattlesnake Creeks. Interstate 15, Highway 278, and the Union Pacific Railroad cross the quadrangle and the town of Dillon is located in the the northeast corner.

PREVIOUS MAPPING AND METHODS

The most detailed mapping prior to this work was that of Ruppel and others (1993, 1:250,000-scale). New field mapping for this project was completed during 2019, using a USGS 1:24,000-scale topographic base map, 2009 orthoimagery from the National Agricultural Imagery Program (NAIP), and a handheld Trimble Juno GPS for locating sample and field observation point data. Rock samples collected for geochemistry and U-Pb geochronology were processed at the MBMG mineral separation laboratory. A ~100–200 g split of the crushed material was prepared for bulk-rock geochemical analysis and subsequently analyzed by X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) at the Peter Hooper GeoAnalytical Lab, Washington State University. Zircon was isolated from selected samples by standard density and magnetic separation techniques. Zircon separates were analyzed by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) by Jesse Mosolf, MBMG, at the University of California, Santa Barbara.

GEOLOGIC SUMMARY

The Dillon West quadrangle occupies part of a broad intermontane valley that is underlain by extensive Tertiary and Quaternary valley-fill deposits. Paleozoic and Mesozoic sedimentary and Tertiary volcanic rocks underlie the low hills west of the town of Dillon. The quadrangle is located along the eastern margin of the fold-thrust belt and within the Beaverhead Graben (fig. 1), one of several intermontane structural basins formed during the onset of Basin and Range-style extension in southwest Montana (Pardee, 1950; Ruppel, 1982; Sears and Fritz, 1998; Sears and others, 2009).

The oldest exposed rocks are folded and faulted Mississippian through Cretaceous carbonate and clastic rocks. The Mississippian through Permian strata (Mission Canyon Formation, Snowcrest Range Group, and Quadrant Formation) are well exposed in a broad, open, northwest-trending, north-plunging anticline. The nose of the anticline is cut by a fault that places poorly exposed limestone, interpreted on this map as Mission Canyon, against Quadrant Formation. The fault geometry and extent are poorly constrained, but it does not appear to cut the nearby volcanic rocks and is mostly concealed. North of the fault, Pennsylvanian through Cretaceous strata (Quadrant, Phosphoria, Dinwoody, and Blackleaf Formations) occur as isolated, generally northwest-dipping outcrops that are mostly covered by Tertiary units.

Tertiary rhyolitic lava flows and tuffs (table 1) of the Dillon Volcanic Group, fine-grained, ash-rich deposits of the Renova Formation, and coarse gravel deposits of the Sixmile Creek Formation unconformably overlie Paleozoic and Mesozoic rocks. Radiometric data indicate the rhyolites are Eocene (table 2) and are part of the informal "lower Dillon volcanics" (Fritz and others, 2007; Mosolf, in review). The volcanic rocks are overlain by and intercalated with the early Eocene to early Miocene Renova Formation, which was deposited as fluvial, lacustrine, and floodplain deposits in intermontane basins in southwest Montana (Kuenzi and Fields, 1971; Schwartz and Schwartz, 2013). Although poorly exposed, rare bedding indicates the Renova Formation is gently tilted. Cobble and boulder gravels of the Middle Miocene to Pliocene Sixmile Creek Formation unconformably overlie the Renova Formation. The cobbles and boulders are subangular to well rounded, and locally include large (>3 m diameter) quartzite blocks. The Sixmile Creek Formation is interpreted as fluvial and debris flow deposits that accumulated in the Miocene Beaverhead Graben (Fritz and Sears, 1993; Fritz and others, 2007).

The Tertiary and underlying Paleozoic and Mesozoic rocks are cut by high-angle, northwest- and northeast-trending faults associated with Cenozoic Basin and Range extension. The concealed, northeast-trending fault mapped west of the Beaverhead River is inferred from seismic reflection profiles (profiles gg' and hh' on map; see Uthman and Beck, 1998 for description of profiles). The seismic data indicated bedrock at 145 m (475 ft) at the southeast end of the profile gg', and valley-fill deposits but no bedrock in profile hh', suggesting a possible down-to-east fault. The concealed fault may connect with one of several east-dipping normal faults shown by Lopez and Schmidt (1985) on their interpretation of seismic reflection data from the northern Beaverhead Valley (see fig. 1 for location of the seismic profile shown in Lopez and Schmidt, 1985). The Quaternary Blacktail Fault crosses the southwest corner of the map. Its location is inferred based on mapping by Tysdal (1988) in the south-adjacent 7.5′ Gallagher Mountain quadrangle.

The youngest deposits in the quadrangle are Quaternary surficial and glacial deposits. Pleistocene glacial outwash along Rattlesnake Creek; broad, coalescing alluvial fans along Blacktail Deer Creek; and alluvium along the Beaverhead River overlie older Tertiary deposits.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated gravel, sand, silt, and clay with cobbles and boulders deposited along the Beaverhead River and tributary streams. Clasts generally subrounded to well rounded and consist predominantly of quartzite. Thickness as much as 10 m (33 ft).

Qac **Alluvium and colluvium (Holocene and Pleistocene?)**—Unconsolidated, locally derived slope and sheet wash deposits consisting of angular rock fragments and gravel, sand, and silt. Rock fragments generally pebble size and larger. Thickness generally less than 10 m (33 ft).

Qaf **Alluvial-fan deposit (Holocene and Pleistocene)**—Unconsolidated, poorly sorted, cobbles, gravel, sand, and silt forming fan-shaped deposits. The large alluvial fan in the southeast part of the map includes coalescing fan deposits formed along the margins of the Blacktail Deer Valley. Estimated thickness less than 10 m (33 feet).

Qalo **Alluvium, older (Holocene and Pleistocene)**—Unconsolidated, stratified to unstratified gravel, sand, silt, and clay deposited by rivers and streams prior to deposition of Qal. Adjacent to but at elevations higher than Qal. In the southwest part of map, may include alluvial-fan deposits. Estimated thickness up to 0–30 m (0–100 ft).

Qafo **Alluvial-fan deposit, older (Holocene and Pleistocene)**—Poorly sorted gravel, sand, and silt with angular to well-rounded cobbles that consist dominantly of Archean basement clasts and quartzite. Deposits occur on gentle slopes and overlie older Tertiary deposits. Thickness up to 5 m (15 ft).

Qgo **Glacial outwash deposit (Pleistocene)**—Weakly stratified deposit of sand and gravel with abundant, locally derived, rounded to sub-rounded cobbles and boulders. Quartzite and feldspathic quartzite clasts are most abundant; weathered granitic clasts, argillite, hornfels, limestone, sandstone, and volcanic clasts are less abundant. Deposit borders Rattlesnake Creek and forms the distal part of the large outwash fan underlying Argenta Flats west of the quadrangle. Domestic well logs indicate the gravels are as much as 13 m (42 ft) thick and are underlain by up to 90 m (295 ft) of clay-rich gravel and cobble layers that may also be outwash.

Tsc **Sixmile Creek Formation, undivided** (Tertiary: Miocene–Pliocene)—Unconsolidated boulder and cobble gravel with a matrix of moderate brown sand and silt. Boulders and cobbles are subangular to well rounded (some up to 3 m in diameter), consisting dominantly of quartzite, with subordinate sandstone, argillite, limestone, chert, volcanic, and plutonic rock. In some areas, the clasts are predominantly moderate yellowish brown (10 yr 4/2) to dark yellowish orange (10 yr 6/6), subrounded to well-rounded quartzite. Elsewhere the cobbles are multi colored. The significance of the clast color is unclear but may represent different deposits within the Sixmile Creek Formation. Gravels with very large quartzite boulders of Quadrant Formation may be debris flow deposits equivalent to the Sweetwater Creek member of the Sixmile Creek Formation (Fritz and Sears, 1993; Fritz and others, 2007). Thickness as much as 90 m (300 ft).

Tre **Renova Formation (Tertiary: Oligocene–Miocene)**—Very pale orange, grayish orange, white, and pale yellowish brown tuffaceous siltstone, tuff, and fine- to coarse-grained sandstone. Discontinuous coarse sandstone intervals are poorly sorted, often micaceous, with angular to well-rounded granules, pebbles, and cobbles. Cobble size clasts are predominantly quartzite and volcanic rock. In the northwest part of the map, occurs as poorly exposed, thin (< 15 m, 50 ft) deposits overlying volcanic and Paleozoic bedrock. Thicker deposits occur in the eastern part of the map, and in the subsurface of the Beaverhead Valley, where it is estimated to range from 450 to 900 m (1,500 to 3,000 ft) thick (Hanna and others, 1993).

Tbrt **Barretts Rhyolite and Tuff (Tertiary: Eocene)**—Light pink, purple, and gray rhyolite (75.82–76.39 wt. percent SiO_2, table 1) that forms resistant ridges, blocky outcrops, and talus slopes. Contains phenocrysts of smoky quartz (<5 percent; 1–3 mm), euhedral plagioclase (<20 percent; 1–2 mm), euhedral biotite (<5 percent; <1 mm), and hornblende (<5 percent; 1 mm) in a waxy groundmass of cyptocrystalline quartz. Flow-banding, dramatic flow-folding, autobrecciation, and vitrophere are common; a prominent interval of vitrophere up to 10 m (33 ft) thick occurs near the base of the unit locally. Rhyolite flows are intercalated with subordinate tuff intervals exhibiting a similar mineral assemblage; a stratified tuff containing poorly sorted clasts of volcanic debris underlies the rhyolite sequences locally. U-Pb zircon samples from adjacent mapping (Dalys and Burns Mountain 7.5′ quadrangles, Mosolf, in review) yielded ages spanning 47.1 ± 0.3 to 47.9 ± 0.3 Ma.

Thgt **Hennebury Gulch Tuff (Tertiary: Eocene)**—White, light brown, and orange, lithic-vitric tuff. Composed of crude bedforms that are ~1–2 m thick and lacking internal structure. Contains broken phenocrysts (up to ~30 percent) of quartz, feldspar, biotite, and occasional amphibole in a vitric groundmass composed of cuspate glass shards that are mostly fresh but are devitrified locally. Tuff intervals commonly include small fragments (~5 mm) of pumice, accidental volcanic clasts (up to ~1 m), and petrified wood. Thin intervals of planar, low-angle cross-bedded tuffaceous sand occur locally. This unit is poorly exposed in the quadrangle but forms slopes under resistant ridges of basaltic lavas in the south-adjacent Gallagher Mountain quadrangle. A sample (JM19DW10) from the southwest corner of the map yielded a U-Pb age of 48.1 ± 0.4 Ma (table 2). As thick as 150 m (500 ft).

Tdwr **Dillon West Rhyolite (Tertiary: Eocene)**—Massive, variegated rhyolite (70.07–72.08 wt. percent SiO_2, table 1) flows and subvolcanic intrusions occurring in shades of red/pink, gray, and brown with sparse (<5 percent) phenocrysts of biotite, hornblende, feldspar, and quartz. Individual flows can be vuggy, massive, or exhibit conspicuous flow foliation. Discontinuous intervals of vitrophere and autobreccia occur locally. The breccia intervals are well exposed north of peak 5856 in sec. 11, T. 7 S., R. 9 W. Six samples (table 2) yielded U-Pb zircon ages spanning 49.2 ± 0.2 to 49.9 ± 0.2 Ma.

Kblf **Blackleaf Formation, Flood Member (Early Cretaceous)**—Pale brown to gray, fine- to medium-grained and locally coarse-grained to conglomeratic, quartz- and chert-rich lithic sandstone. Trough and ripple crossbedding common in sandstone. Overlies poorly exposed, moderate yellowish brown, calcareous, mudstone. Interpreted as Blackleaf Formation based on regional descriptions to the north of the quadrangle (Tysdal and others, 1994; Dyman and Nichols, 1988). Exposed in an isolated outcrop about 15 m (50 ft) thick in the northwest part of the quadrangle.

Trd **Dinwoody Formation (Lower Triassic)**—Interbedded shale, limestone, and calcareous sandstone characterized by distinctive pale to light grayish brown weathered surfaces. Occurs as an isolated, ~1 m (3 ft) thick outcrop in the northwest part of the quadrangle but regionally is up to 245 m (800 ft) thick.

Pp **Phosphoria Formation (Permian)**—Brownish gray to dark gray, thin- to thick-bedded chert, grayish brown quartz sandstone, and cherty sandstone. Forms an isolated low ridge of poorly exposed outcrop and float. Regionally approximately 183–215 m (600–700 ft) thick but only about 20 m (60 ft) exposed in quadrangle.

IPq **Quadrant Formation (Pennsylvanian)**—Light gray to light yellowish brown, fine-grained, medium- to thick-bedded, flat-laminated to cross-bedded, vitreous quartz sandstone. Forms resistant ridges typically covered with conifers. Thickness approximately 245 m (800 ft).

IPMsr **Snowcrest Range Group (Pennsylvanian and Mississippian)**—Formerly mapped as Amsden Formation in this area (Myers, 1952; Hobbs, 1967) but now defined as the Snowcrest Range Group, which contains the Conover Ranch, Lombard, and Kibbey Formations (Wardlaw and Pecora, 1985). Total exposed thickness is up to 170 m (558 ft) but localized outcrop-scale folds, especially in the Lombard Formation, make thickness estimates problematic.
Conover Ranch Formation—Pale reddish and pale yellowish, thin-bedded, calcareous mudstone with minor interbeds of limestone, calcareous sandstone, and siltstone. Some beds contain brachiopods, bryozoan debris, crinoid columnals, and belemnite fragments.
Lombard Formation—Upper unit is fossilifereous, thin- to thick-bedded, lime-mudstone and limestone with rare chert lenses. Lower unit is poorly fossiliferous, thin to thick, indistinctly bedded, lime-mudstone and gray limestone. Brachiopods fossils and coquina lenses are common. Rugose corals and oncolites are also present.
Kibbey Formation—Gray quartzite and yellowish, calcareous sandstone beds interbedded with siltstone and shale.

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, and 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. Thickness variable as a result of deformation but estimated to be up to 360 m (1,375 ft) thick.

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Table 1. Bulk rock geochemical data for volcanic rock samples collected in the Dillon West 7.5′ quadrangle.

Sample ID	JM19DW02	JM19DW03	JM19DW04	JM19DW06	JM19DW07	JM19DW09	JM19DW11	KM19DW28	KM19DW50
Map unit	Tbrt	Tdwr	Tdwr	Tdwr	Tdwr	Tdwr	Tbrt	Tdwr	Tdwr
Latitude	45.132	45.235	45.239	45.249	45.243	45.215	45.129	45.218	45.186
Longitude	-112.745	-112.695	-112.670	-112.657	-112.655	-112.667	-112.740	-112.705	-112.702
Major elements (wt%)									
SiO_2	75.82	70.31	70.07	71.34	71.99	71.60	76.39	71.93	72.08
TiO_2	0.05	0.26	0.24	0.17	0.17	0.18	0.02	0.17	0.17
Al_2O_3	13.16	14.88	14.82	14.46	14.52	14.54	12.64	14.53	14.63
FeO	0.88	2.31	2.14	1.97	1.91	1.94	0.76	1.79	1.91
MnO	0.08	0.07	0.07	0.06	0.10	0.03	0.11	0.03	0.03
MgO	0.01	0.17	0.31	0.26	0.10	0.24	0.10	0.19	0.12
CaO	0.40	1.83	1.52	1.06	1.19	1.20	0.25	1.19	1.12
Na_2O	4.32	3.99	3.95	3.48	3.86	3.84	3.95	3.84	4.03
K_2O	4.59	4.75	4.98	5.15	5.13	4.97	4.30	5.08	5.08
P_2O_5	0.02	0.08	0.07	0.05	0.04	0.05	0.01	0.05	0.03
Sum	99.32	98.64	98.17	98.01	99.01	98.61	98.55	98.79	99.20
LOI	0.28	0.96	1.28	1.31	0.51	1.05	1.12	0.87	0.42
Trace elements (ppm)									
Ni	0.99	2.19	2.44	1.99	2.19	2.35	0.10	2.10	2.24
Cr	3.07	6.17	4.83	4.33	3.69	5.94	3.05	2.75	5.32
V	5.69	15.61	10.80	5.77	8.32	6.39	5.84	8.35	6.22
Ga	29.01	17.95	17.46	17.06	17.68	17.08	30.47	17.81	18.11
Cu	2.82	5.32	2.99	2.88	2.69	2.15	2.55	2.50	2.39
Zn	68.56	57.73	59.55	46.69	48.31	55.25	83.27	53.08	48.66
La	9.55	80.36	82.20	94.75	87.82	85.97	8.53	86.21	83.85
Ce	25.01	134.77	136.76	144.46	145.24	138.95	20.83	144.04	136.56
Pr	2.30	13.62	14.15	16.04	14.96	14.56	2.60	14.64	13.71
Nd	8.64	44.06	45.40	51.05	47.49	45.12	10.35	46.31	42.90
Sm	3.76	6.98	7.15	7.92	7.28	6.58	5.05	7.04	5.97
Eu	0.12	1.52	1.56	1.60	1.50	1.44	0.07	1.39	1.41
Gd	5.74	4.84	5.07	5.52	5.12	4.31	7.55	4.59	3.67
Tb	1.43	0.68	0.74	0.81	0.76	0.57	1.81	0.65	0.50
Dy	10.49	3.81	4.17	4.57	4.10	3.02	12.71	3.53	2.57
Ho	2.22	0.71	0.81	0.89	0.79	0.56	2.66	0.65	0.46
Er	6.50	1.90	2.27	2.46	2.13	1.45	7.77	1.67	1.20
Tm	1.05	0.28	0.32	0.38	0.30	0.21	1.30	0.24	0.19
Yb	6.86	1.71	2.05	2.34	1.83	1.38	8.59	1.54	1.24
Lu	1.02	0.27	0.33	0.37	0.26	0.20	1.32	0.24	0.19
Ba	57.59	2,141.48	2,148.03	2,017.42	2,157.44	2,034.27	62.02	2,057.31	2,039.74
Th	41.70	25.93	26.34	28.20	28.36	27.84	42.23	28.63	29.23
Nb	90.34	27.97	27.94	29.04	28.96	27.77	99.59	29.05	24.83
Y	67.97	18.94	21.91	24.36	20.59	14.70	82.94	17.65	11.96
Hf	7.38	7.49	7.13	6.28	6.41	6.36	8.67	6.36	6.22
Ta	13.77	1.66	1.68	1.81	1.80	1.75	18.06	1.78	1.78
U	9.02	4.00	4.64	4.34	4.51	2.44	7.82	3.33	2.50
Pb	106.56	28.63	30.82	32.58	34.08	28.21	139.96	33.73	33.90
Rb	572.97	142.57	144.45	152.69	152.43	169.01	694.01	152.00	165.89
Cs	19.16	2.29	1.32	2.29	2.26	2.94	28.87	2.68	2.21
Sr	12.38	319.81	305.79	231.95	246.20	245.05	11.10	240.88	242.19
Sc	2.53	3.74	3.26	2.81	2.70	3.12	2.50	2.74	2.51
Zr	101.34	293.02	286.53	230.79	233.56	236.99	99.00	231.69	221.41

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. U-Pb zircon geochronology.

Sample ID	Map Unit	Latitude	Longitude	Age (Ma)	2σ
JM19DW03	Tdwr	45.235	-112.695	49.6	0.3
JM19DW04	Tdwr	45.239	-112.670	49.2	0.2
JM19DW06	Tdwr	45.249	-112.657	49.9	0.2
JM19DW09	Tdwr	45.215	-112.667	49.6	0.3
JM19DW10	Thgt	45.131	-112.743	48.1	0.4
KM19DW28	Tdwr	45.218	-112.705	49.3	0.2
KM19DW50	Tdwr	45.186	-112.702	49.6	0.2

Note: Reported ages are the weighted mean of the ^{207}Pb corrected $^{206}Pb/^{238}U$ ages obtained for each sample. MSWD is the Mean Square Weighted Deviation.
[a] Number of spot analyses used to calculate weighted mean age. Zircon separates were prepared at MBMG and analyzed by LA-ICPMS at the University of California, Santa Barbara. Latitudes and longitudes are in the 1984 World Geodetic Survey (WGS84) datum.

MBMG
Montana Bureau of Mines and Geology

Geologic Map 91

Geologic Map of the Dillon West 7.5′ Quadrangle, Beaverhead County, Montana

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