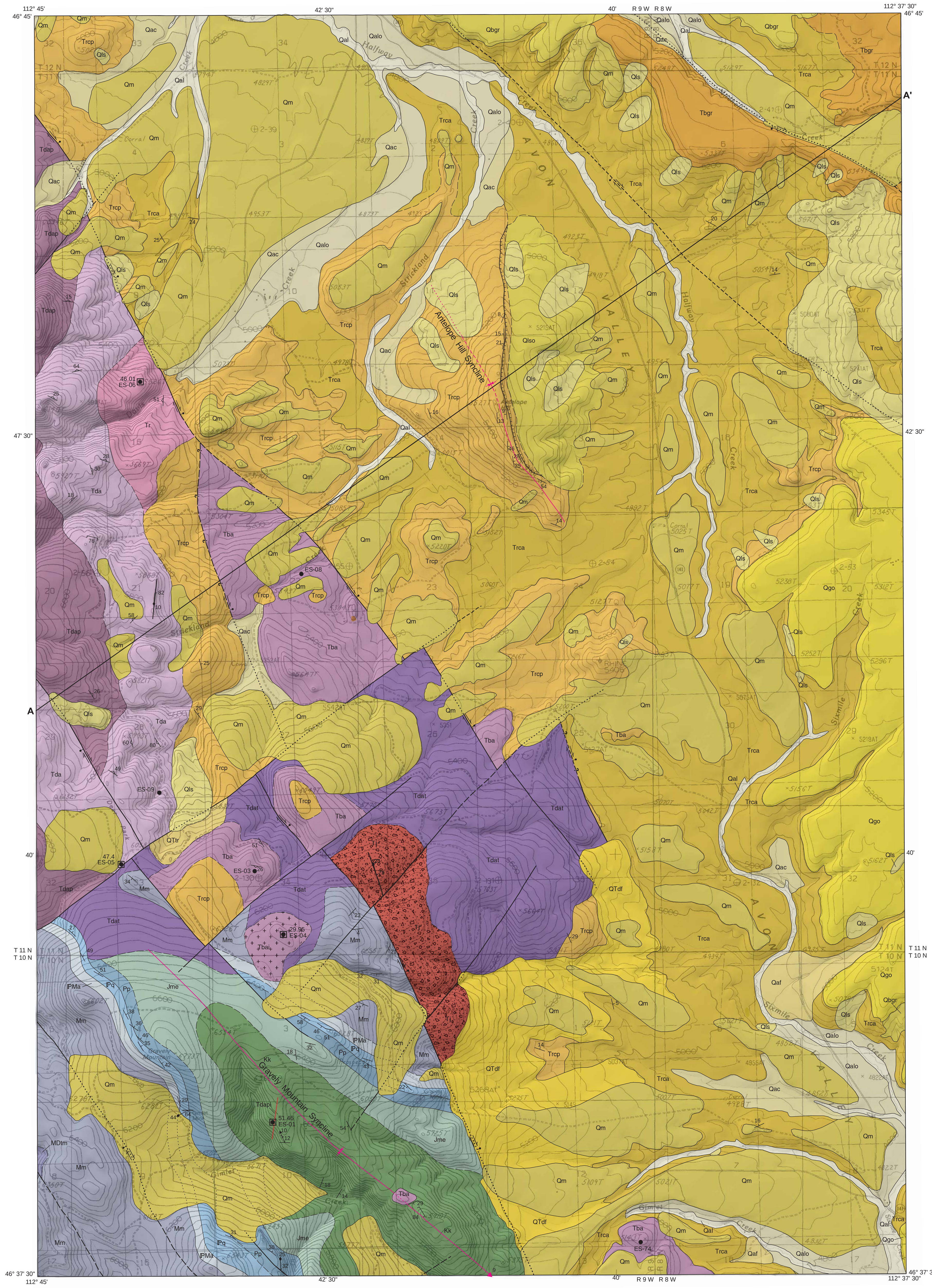
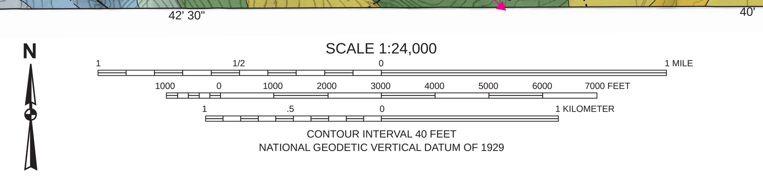


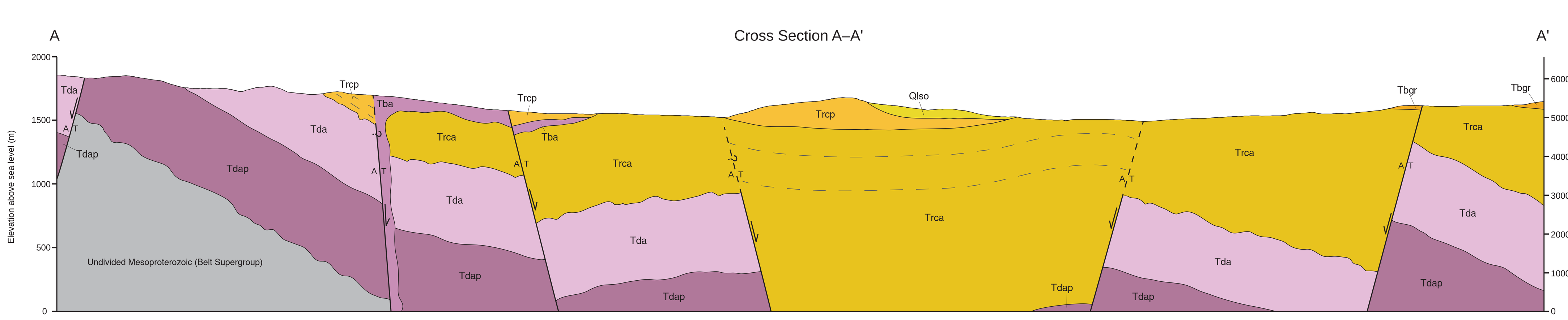
Base map produced by the United States Geological Survey
Control by: USGS, NOS/NOAA, and USFS
Compiled from aerial photographs taken 1984
Field checked: 1985 Map edited: 1989
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 1° 14' East
1989 Magnetic NorthDeclination: 16° 30' East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum



CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

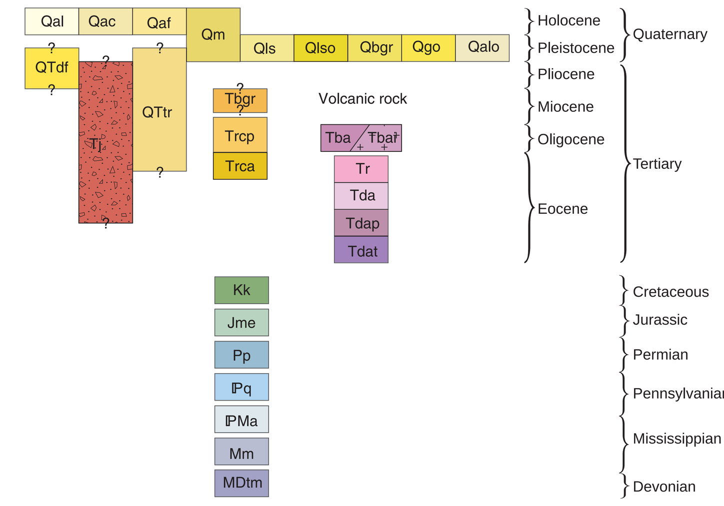
Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4167
http://mbmg.mtech.edu

Cross Section A–A'



No vertical exaggeration
Surficial units not shown
Bedding lines
A, away
T, toward
Interpretation supplemented by gravity data (Knatterud and others, 2015, 2017)

CORRELATION DIAGRAM



MAP SYMBOLS

Contact: dashed where approximately located; dotted where concealed

Fault: dashed where inferred; dotted where concealed; bar and ball on downthrown side; arrows indicate relative lateral movement; queried where identity or existence questionable

Syncline: showing trace of axial plane and plunge direction; dashed where approximately located; dotted where concealed

Landslide scarp

Strike and dip of inclined beds

Horizontal beds

Strike and dip of cleavage

Strike and dip of joints

Bedding/cleavage intersection

Strike and dip of volcanic foliation

Strike and dip of fault plane, and trend and plunge of slickenlines

29.95 U-Pb zircon radiometric age data sample point with age in Ma

ES-04 Geochemical sample point with sample number

INTRODUCTION

The Gravely Mountain geologic map is the product of fieldwork completed in 2012, with reference to previous regional mapping and research by Weber and Witkind (1979; scale 1:62,500), French (1979; scale 1:62,500), Callmeyer (1984; scale 1:41,700), and Lewis (1998; scale 1:250,000). Development of the Tertiary volcanic stratigraphy was based on work by Callmeyer (1984) and defined by a combination of petrography, geochemistry, and radiometric dating. Tertiary sedimentary units were defined by lithofacies assemblages and correlated to deposits exposed in other western Montana valleys (Robinson, 1967; Rasmussen, 1989). The Paleozoic and Mesozoic units were divided and mapped following descriptions by Kauffmann and Earll (1963) for the Garnet–Bearmouth area.

The Gravely Mountain 7.5' quadrangle is located in west-central Montana, where it covers parts of the eastern Garnet Range and the adjacent Avon Valley (fig. 1), north of Avon, Montana. The map area lies within the eastern extent of the Lewis and Clark Fault Zone, approximately 40 km (25 mi) northeast of the Anaconda Metamorphic Core Complex, and within the regionally extensive Eocene Challis–Kamloops–Absaroka volcanic belt. Folded Mississippian through Early Cretaceous continental and marine strata are the oldest rocks exposed. Eocene–Oligocene volcanic and sedimentary rocks rest on an angular unconformity that truncates the Paleozoic–Mesozoic units. Tertiary sedimentary deposits occur at low elevations in the Avon Valley, and are locally intercalated with Oligocene basalt flows along the valley margin. Tertiary–Quaternary mass movement deposits have extensively modified the Tertiary volcanic and sedimentary units.

DESCRIPTION OF MAP UNITS

The geologic map shows rock and poorly lithified units exposed at the surface or covered by thin soil and colluvium. Surficial sedimentary and mass movement deposits are shown where they are thick and extensive enough to be mapped. Minerals in igneous rock units are listed in order of decreasing abundance. Grain size classification of unconsolidated and consolidated sediment is based on the Wentworth scale (Lane, 1947). Multiple lithologies within a rock unit are listed in order of decreasing abundance. Bed thickness, formation thickness, distances, and elevation are listed in metric and English units.

ALLUVIAL AND COLLUVIAL DEPOSITS

Qal **Alluvium (Quaternary: Holocene)**—Gravel, sand, silt, and clay along streams and their tributaries. Clasts are generally cobbles and smaller, and are rounded to subrounded.

Qac **Alluvium and colluvium (Quaternary: Holocene)**—Silt, sand, granules, and pebbles deposited on slopes by sheetwash alluvium incorporated with locally derived fine-grained colluvium.

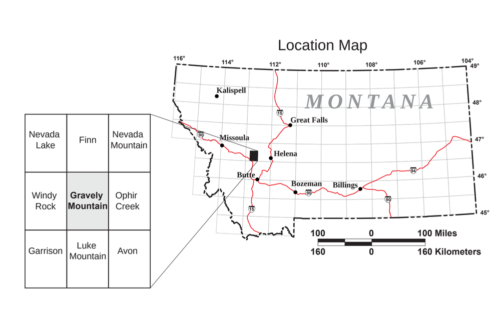
Qaf **Alluvial-fan deposit (Quaternary: Holocene)**—Gravel, sand, silt, and clay in fan-shaped deposit at the mouth of a tributary of Sixmile Creek (fig. 1). Clasts are iron-oxide stained, and reworked from an associated glacial outwash deposit.

Qm **Mantle (Quaternary: Holocene and Pleistocene)**—Deposit that includes sheetwash alluvium, colluvium, coarse-grained (pebble, cobble, small boulder) lag from older debris-flow deposits, and regolith.

Qbgr **Boulder gravel (Quaternary: Pleistocene)**—Deposits that were likely reworked from older boulder gravel (Tbgr) or glacial outwash deposits (Qgo). Dominantly clast-supported, subrounded pebbles and cobbles.

Qgo **Glacial outwash (Quaternary: Pleistocene)**—Deposits along Sixmile Creek that represent the terminus of a large glacial outwash fan that continues into the east-adjacent Ophir Creek 7.5' quadrangle. Fan is about 6.5 km (4 mi) wide. Dominantly reworked, subrounded, iron-stained pebbles and cobbles, dominantly clast-supported.

Qalo **Alluvium: older than Qal (Quaternary: Pleistocene)**—Deposits beneath floodplains, assumed to be similar to Qal, but generally covered with fine-grained floodplain deposits.



Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G12AC20277.
GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG. Editing: Susan Barth, MBMG.

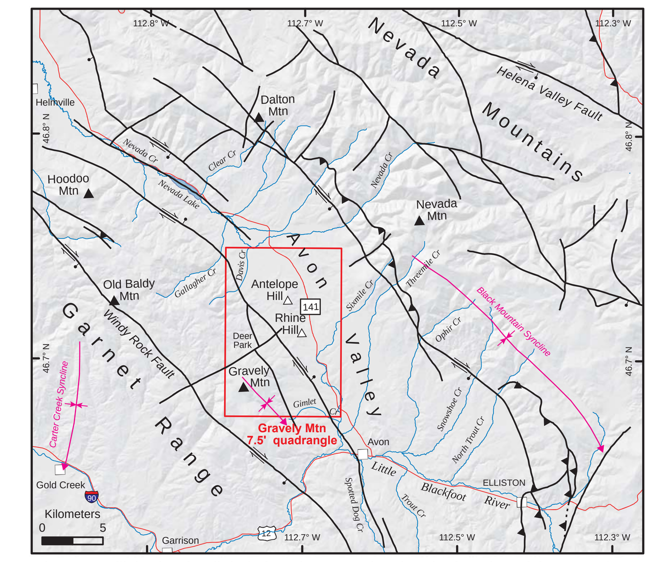


Figure 1. Hillshade of a digital elevation map showing the location of the Gravely Mountain 7.5' quadrangle and major tectonic structures (modified from McDonald and others, 2015).

MASS MOVEMENT DEPOSITS

Qls **Landslide deposit (Quaternary: Holocene)**—Mass-wasting deposit of rotated or chaotic beds. The bentonitic Climbing Arrow Member of the Renova Formation and units that immediately overlie it are particularly prone to landslide development.

Qlso **Landslide deposit, older than Qls (Quaternary: Holocene or Pleistocene)**—Deposit on the east side of Antelope Hill that slid downslope through mass wasting, resulting in a landslide scarp. The topographic expression of Qlso is more subdued than secondary landslide deposits (Qls) developed within the older deposit. Deposit slid on bentonitic Climbing Arrow Member of the Renova Formation (Trca).

QTdf **Debris-flow deposit (Quaternary or Tertiary)**—Matrix-supported deposits in the southern part of the map that include angular and subangular boulders and smaller clasts derived from the west side of the valley. Mapped primarily on the basis of boulder lag on a topographically irregular surface.

HYDROTHERMAL DEPOSITS

QTtr **Travertine (Quaternary–Tertiary?)**—Coarsely crystalline calcium carbonate that commonly consists of beds 3–50 cm thick that are generally disturbed/chaotic. Carbonate deposition is no longer active and karst topography covered by soil has developed. Generally poorly exposed.

Tj **Jasperoid breccia (Tertiary?)**—Light gray to red, dense, silicified breccia. Contains angular clasts of limestone in a jasperoid matrix; locally shows liesegang banding. Forms "pipes" at the intersection of NW- and NE-trending faults.

TERTIARY SEDIMENTARY DEPOSITS

The youngest Tertiary sedimentary deposits are Miocene (?) boulder gravels associated with a fault system along the northeast edge of the Avon Valley (McDonald and others, 2016). Poorly lithified and fine-grained sedimentary deposits underlying the Avon Valley are identified as the Cabbage Patch and Climbing Arrow Members of the Renova Formation through lithostratigraphic correlation to units of corresponding age in adjacent valleys (Rasmussen, 1989). These deposits are interpreted to have formed in lacustrine and associated environments, and are generally composed of limestone, marlstone, bentonitic mudstone, carbonaceous shale, and subordinate sandstone, pebble or granule conglomerate, gastropod coquina, volcanic ash, and lignite. Renova Formation exposed at the surface is as much as 180 m (590 ft) thick, and a recently completed gravity survey suggests that as much as 1,500 m (4,920 ft) of poorly consolidated sedimentary deposits underlie the Avon Valley (Knatterud and others, 2015). Bentonitic mudstone in the Renova Formation is prone to landslide development.

Tbgr **Boulder gravel (Tertiary: Miocene?)**—Dominantly matrix-supported, but locally clast-supported deposits. Clasts range from pebbles to large boulders in a clay/silt/sand matrix. Clast composition dominantly Mesoproterozoic Belt Supergroup quartzite with subordinate volcanic and plutonic rock. Loen (1990) and Schmidt and others (1994) interpreted the deposit in the east-adjacent Ophir Creek 7.5' quadrangle to be Miocene age and to contain placer gold. Estimated thickness as much as 300 m (985 ft).

Trcp **Renova Formation: Cabbage Patch member (Tertiary: Miocene and/or Oligocene)**—Gastropod-bearing marlstone, thinly bedded limestone, tufa, travertine, and local gastropod coquina that in many places overlie a coarse-grained sandstone with plant impressions, petrified wood, and associated shale. Sandstone contains lenses of pebble conglomerate with rounded to subrounded clasts. Carbonate beds are locally silicified to white-weathering, gray porcellanite and variegated chert. Best exposed on Antelope Hill between Strickland and Halfway Creeks where it overlies the Climbing Arrow Member (Trca). Faint outlines of gastropods are discernible in recrystallized limestone along the crest of Antelope Hill, coinciding with the axial trace of the Antelope Hill syncline. Member overlies volcanic rock at lower elevations in the Garnet Range (fig. 1), commonly occurring as float that may be a lag deposit. Native peoples quarried silicified beds, named the Avon Chert by archeologists, near Antelope and Rhine Hills (fig. 1) . The Avon chert has a distinctive laser ablation inductively coupled plasma mass spectrometry signature that has been used to track archeological artifacts as far east as Illinois (Roll and others, 2005). Near Rhine Hill, the unit is brecciated and contains rounded rip-up clasts. Tuffaceous siltstone and quartzose sandstone exposed on Antelope Hill east of Halfway Creek were included in the map unit. Exposed thickness approximately 90 m (295 ft).

Trca **Renova Formation: Climbing Arrow Member (Tertiary: Eocene)**—Pale olive, light olive gray, moderate olive brown, and medium light gray bentonitic mudstone and yellowish gray siltstone. Contains lenses of brownish gray sandstone, and gravel/conglomerate in which pebbles dominate in a sand/granule matrix. Sandstone is dominantly medium- to coarse-grained. Gravel or conglomerate consists of clast-supported lenses of rounded granules, pebbles, and cobbles of rhyolite porphyry and other volcanic lithologies in a sandy matrix. Mudstone typically displays "popcorn" weathering, large desiccation cracks, and is prone to landslide development. Exposed thickness is approximately 90 m (295 ft).

TERTIARY VOLCANIC ROCKS

Tertiary volcanic rocks were formed from effusive-type eruptions during the Eocene and Oligocene, and likely came from multiple vents. The extrusive Eocene volcanic units include trachyandesite, trachydacite, and rhyolitic lavas and tuffs (fig. 2; table 1). All of these sequences generally have a high-K, calc-alkaline affinity and exhibit a "subduction signature" of enriched, large-ion lithophile elements and depleted high field-strength elements. Eocene volcanism was synchronous with regional crustal transtension and rapid exhumation of the nearby Anaconda Metamorphic Core Complex (~53–40 Ma; Foster and others, 2007). Oligocene basalt to trachyandesite lavas occur along the margin of the Avon Valley and are locally intercalated with Tertiary sediments. These rocks are alkalic and exhibit a shoshonitic affinity.

Tba / Tbai **Basalt to trachyandesite (Tertiary: Oligocene)**— Black, fine-grained, massive basalt to trachyandesite lava flows (Tba) and intrusion (Tbai) with phenocrysts of plagioclase, clinopyroxene and orthopyroxene, biotite, olivine, and rare resorbed quartz. Locally vesicular, weathers to light brown, and forms angular to sub-rounded blocks; some flows have columnar joints and distinct autobreccia. The aphanitic groundmass consists mainly of plagioclase microcrystals, but also includes pyroxenes, biotite, and Fe-oxides. This unit yielded an U-Pb zircon age of 29.95 ± 0.17 Ma (table 2). Similar basaltic lavas near Nevada Lake (fig. 1) yielded a K-Ar age of 32.3 ± 0.17 Ma (Reynolds, written commun., 2015).

Tr **Rhyolite (Tertiary: Eocene)**—Porphyritic rhyolite with distinct red, white, and green laminations 2–20 mm thick. Contains phenocrysts of subhedral plagioclase, amphibole, biotite, and rare quartz within an aphanitic groundmass of devitrified glass and flow-aligned microcrystals of euhedral plagioclase, hornblende, and biotite. Mafic phenocrysts are generally altered to opaque Fe-oxides. The rocks exhibit well-developed flow banding and are brecciated locally. Possibly formed as a lava dome or plug. Occurs near Davis Creek, where it overlies or possibly intrudes Eocene lava flows (Tda). This unit yielded an U-Pb zircon age of 46.01 ± 0.23 Ma (table 2). Thickness is 0–600 m (0–1,970 ft).

Tda **Trachyandesite (Tertiary: Eocene)**—Dark gray and dark greenish gray, aphanitic to weakly porphyritic trachyandesite. Lava flows commonly exhibit a conspicuous flow foliation and form flaggy, angular talus, often with red iron oxide stain on parting surfaces. Aphanitic lavas exhibit a strong trachytic texture consisting mainly of plagioclase microcrystals, but also include minor amounts of pyroxene, magnetite, and volcanic glass. Porphyritic flows contain <10–15 percent phenocrysts of plagioclase, amphibole, and occasional biotite. Thickness is 0–480 m (0–1,575 ft).

Tdap **Trachydacite to trachyandesite porphyry (Tertiary: Eocene)**—Gray-, green-, and red-weathering porphyritic trachydacite to trachyandesite lava flows containing subhedral to euhedral phenocrysts of plagioclase (up to ~5 mm) and minor amounts of amphibole, biotite, and quartz. The aphanitic groundmass commonly has a trachytic texture and consists mainly of aligned micro-laths of plagioclase, but also includes amphibole, biotite, and magnetite. Often, up to several meters of autobrecciated rock surrounds coherent interiors of individual lava flows. Commonly weathers to blocks or plates, with some outcrops forming hoodoos or spires. Rock samples collected in the west-adjacent Windy Rock quadrangle yielded U-Pb ages of 47.1 ± 0.29 to 46.74 ± 0.27 Ma (Mosolf, 2016). Thickness is 0–600 m (0–1,970 ft).

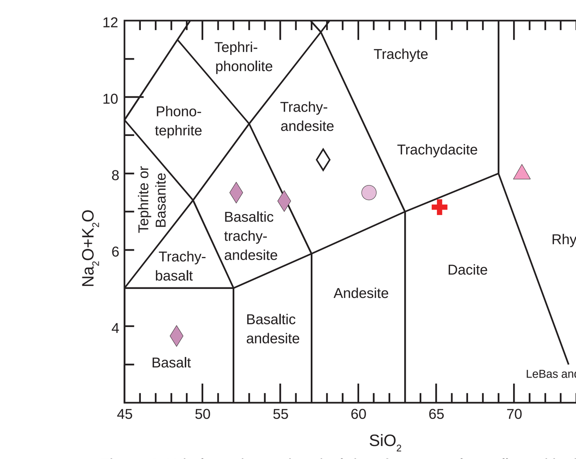


Figure 2. Whole-rock geochemical data from samples collected in the Gravely Mountain 7.5' quadrangle. Data are normalized and plotted on a total alkali–silica diagram (Na_2O+K_2O vs. SiO_2). After LeBas and others (1986).

Tdat **Dacitic tuff (Tertiary: Eocene)**—Massive or flow-banded variably silicified dacite tuff that contains phenocrysts of plagioclase, quartz, biotite, and amphibole. The groundmass is almost entirely devitrified glass with some magnetite. Scoriaceous pumice lapilli occur locally and account for up to ~50 percent of the rock. Pumice is commonly flattened into fiamme attributed to compaction during diagenesis rather than by welding of a hot ash-flow. Fine-grained intervals contain preserved plant and wood fragments, and are possibly water-lain. Poorly exposed and therefore often distinguished by flaggy chips that are white, yellow, and orange weathering. Relatively good exposures occur in a quarry near Deer Park (fig.1) and in roadcuts 1–2 mi SW of Rhine Hill (fig.1). An U-Pb zircon age of 47.4 ± 0.19 Ma (table 2) was obtained for this unit. Thickness is 0–150 m (0–490 ft).

Tdapi **Dacite porphyry, intrusion (Tertiary: Eocene)**—Porphyritic dike, 2–3 m (7–10 ft) wide, that cross-cuts the Gravely Mountain syncline. Contains phenocrysts of plagioclase, hornblende, and rare quartz in an aphanitic groundmass. The dike is the oldest magmatic unit identified in the map area and yielded a U-Pb zircon age of 51.46 ± 0.25 Ma (table 2).

MESOZOIC AND PALEOZOIC STRATIGRAPHY

A thick succession of tilted, faulted, and folded Mississippian through Early Cretaceous marine and continental strata underlies the southwest part of the map area. The Phosphoria Formation (Pp) contains phosphate-rich beds that were historically mined; several adits and abandoned phosphate mines, including the Gravely mine, are located near the contact between the Quadrant and Phosphoria Formations.

Kk **Kootenai Formation (Early Cretaceous)**—Deposits of mudstone, siltstone, limestone, salt-and-pepper sandstone, and conglomerate in four informal members from top to bottom: upper calcareous; upper clastic; lower calcareous; and lower clastic. The upper calcareous member is gray, fine- to medium-crystalline limestone with minor interbedded shale, siltstone, and sandstone. The top is marked by a dark gray coarsely crystalline limestone composed almost entirely of gastropod shells. The upper clastic member consists of green, gray, and maroon siltstone and shale with a few thin calcareous salt-and-pepper sandstone and limestone beds, including a distinctive flat-pebble limestone conglomerate. The lower calcareous member consists of interbedded, dark gray to black, very fine-grained limestone; maroon, green, and gray shale and siltstone; and occasional beds of calcareous concretions. The lower clastic member is maroon and gray sandstone interbedded with minor shale and siltstone. Either hard silica-cemented vitreous sandstone with distinct red jasper grains or lenticular beds of red-brown weathering conglomerate with pebbles and cobbles of black chert and white quartzite mark the base of the Kootenai Formation. Good exposures occur in roadcuts along Gimlet Creek (fig.1). Total thickness is approximately 330 m (1,085 ft).

Jme **Morrison Formation and Ellis Group, undivided (Late to Middle Jurassic)**
Morrison Formation (Late Jurassic)—Poorly exposed olive green and gray- to grayish-green mudstone, shale, siltstone, and minor sandstone. Siltstone near base is calcareous and flaggy. Dense, salt-and-pepper sandstone and minor concretionary limestone occur in the upper part. Thickness is approximately 47–67 m (154–220 ft).

Ellis Group (Late to Middle Jurassic)—
Swift Formation: upper part is brown to yellowish brown, often calcareous and glauconitic, salt-and-pepper sandstone with interbedded siltstone and micaceous shale. Basal sandstone contains lenses of black chert-pebble conglomerate. Sparce fossils include oysters, belemnites, and wood fragments. Thickness is approximately 35–75 m (115–246 ft).
Rierdon Formation: dark brownish gray to dark gray calcareous shale, shaly limestone, and limestone. Shales weather yellowish gray or whitish gray. Fossil fragments and ripple marks are common on bedding planes. Brown, oolitic or sandy limestone beds mark the stratigraphic base. Thickness is approximately18–23 m (59–75 ft).
Sawtooth Formation: the upper part is interbedded calcareous shale, siltstone, and limestone; the middle part is very calcareous dark gray shale or argillaceous limestone that weathers creamy white; the lower part is dark gray to black, fossiliferous, calcareous buff-weathering siltstone. Approximate thickness is 75 m (246 ft).

Pp **Phosphoria Formation (Permian)**—Bluish gray and brown weathering sandstone, shale, bedded chert, and oolitic phosphatic rock. The Phosphoria Formation is poorly exposed and difficult to distinguish in the field. Relatively good exposures occur near the Luke Mine in the south-adjacent Luke Mountain quadrangle. Estimated thickness is 80 m (260 ft).

IPq **Quadrant Formation (Pennsylvanian)**—White to tan, fine- to medium-grained, vitreous quartzite that is poorly bedded to massive. Weathers to a greenish gray or rusty brown surface spotted by black lichens. The quartzite is locally brecciated, perhaps by tectonism. The Quadrant Formation is an excellent ridge-forming marker horizon easily distinguishable from most other stratigraphic units. Estimated thickness is 60 m (197 ft).

IPMa **Amsden Formation (Pennsylvanian and Mississippian)**—Reddish brown, fine-grained sandstone, calcareous siltstone, shale, and limestone. A thin interval of pebble conglomerate marks its top. The Amsden Formation is poorly exposed and therefore distinguished by reddish soil or a recessive interval between the underlying Madison Group and the overlying Quadrant Formation. Estimated thickness is 90 m (295 ft).

Mm **Madison Group, undivided (Mississippian)**—Thick sequence of limestone, limestone breccia, and chert that generally forms prominent ridges, cliffs, and hoodoos.
Mission Canyon Formation—Upper part is light to medium gray limestone breccia with interbedded medium-bedded limestone and dolomitic limestone. Breccias contain angular limestone and siltstone clasts in an orange- or red-stained matrix. Lower part is light to dark gray, partly cherty, medium- to very thick-bedded limestone and minor dolomite. Typically fossiliferous and oolitic. Weathers medium to light gray. Thickness is approximately 250 m (820 ft).
Lodgepole Formation—Dark gray, fossiliferous, thin-bedded limestone and silty limestone. Abundant interbeds of dark gray to black chert nodules, ribbons, and beds, especially in lower part. The upper part is more fossiliferous with thick beds and some breccia. Weathers light to medium gray. Thickness is approximately 270 m (885 ft).

MDtm **Three Forks, Jefferson, and Maywood Formations, undivided (Early Mississippian and Late Devonian)**—Thick sequence of shale, siltstone, limestone, and dolomite. Limestone and dolomite of the Jefferson Formation commonly form ridges, cliffs, and spires. The Three Forks and Maywood Formations are poorly exposed. There is only a small occurrence of this unit near the western boundary of the map; it is best observed in the Warm Springs drainage in the west-adjacent Windy Rock 7.5' quadrangle. Thickness is approximately 320 m (1,050 ft).

STRUCTURAL GEOLOGY

FAULTS

NW- and NE-striking, high-angle, oblique-slip faults displace Paleozoic through Tertiary sedimentary and volcanic units along the southwestern edge of the Avon Valley. Large bodies of jasperoid breccia (Tj) and Oligocene basalts (Tba) occur at junctions between these fault systems. Fault-slip data indicate dextral slip on the major NW-striking faults, and related P- and T-axes are compatible with fault initiation in a WNW-trending transtensive shear zone. The northeast edge of the Avon Valley is also bounded by NW-striking faults (McDonald and others, 2016), and gravity models show the valley is floored by a series of parallel, high-angle faults (Knatterud and others, 2015, 2017). Faults bounding and underlying the Avon Valley are interpreted to be an extensional pull-apart structure initiated during Cenozoic transtensive crustal deformation in the eastern Lewis and Clark Fault Zone (Reynolds, 1979; Foster and others, 2007). Numerous strike-slip and oblique-slip focal mechanisms obtained from recent seismic events in the Avon region suggest that the eastern Lewis and Clark Fault Zone remains active as a dextral shear zone (Stickney, 2015).

FOLDS

Mississippian though Cretaceous rocks in the southwest part of the map are deformed by an open and upright syncline that gently plunges to the southeast (Gravely Mountain syncline; fig. 3a). This structure likely formed during Late Cretaceous transpressive shortening within the Lewis and Clark Fault Zone (Sears and Hendrix, 2004). An upright syncline deforms the Renova Formation underlying Antelope Hill in the Avon Valley (fig. 3b). Folding of Tertiary sedimentary deposits was likely synchronous with transtensive faulting and the development of the pull-apart structure underneath the Avon Valley.

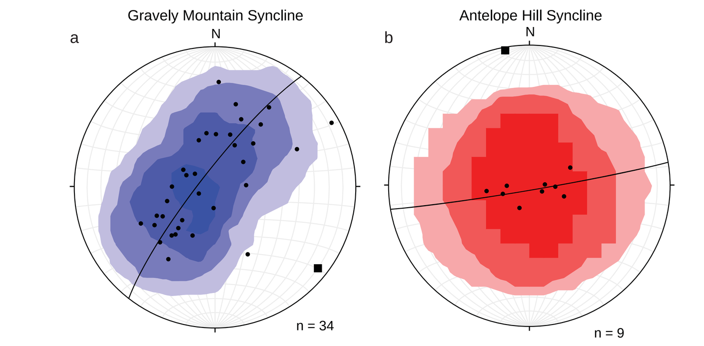


Figure 3. Lower-hemisphere projection of poles to bedding for the (a) Gravely Mountain syncline and (b) Antelope Hill syncline. Data are plotted on an equal-area stereonet and fit with a Kamb contour. Great circles are the cylindrical best fit of the data and black squares represent the fold axes.

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

Sample ID	ES-01	ES-03	ES-04	ES-06	ES-08	ES-09	ES-74
Map unit	Tdapi	Tba	Tbai	Tr	Tba	Tda	Tba
Latitude	46.64	46.66	46.66	46.71	46.69	46.67	46.63
Longitude	-112.72	-112.72	-112.72	-112.74	-112.71	-112.73	-112.66
Major Elements (wt %)							
SiO_2	61.97	50.37	55.45	68.79	52.89	59.74	46.76
TiO_2	0.44	0.85	0.77	0.42	1.26	0.80	1.72
Al_2O_3	14.69	18.77	16.27	15.34	15.86	17.26	16.65
FeO*	2.69	5.68	5.07	2.49	6.71	5.55	10.14
MnO	0.15	0.12	0.11	0.02	0.13	0.06	0.18
MgO	1.66	4.77	2.70	0.30	3.64	2.32	7.39
CaO	6.18	7.18	6.49	2.10	6.92	4.74	9.73
Na_2O	3.65	5.34	3.92	3.87	3.89	4.88	2.77
K_2O	3.47	2.16	4.44	4.11	3.39	2.62	0.98
P_2O_5	0.13	1.30	0.80	0.14	1.05	0.47	0.42
Sum	95.02	96.55	96.01	97.58	95.72	98.44	96.75
LOI	3.84	3.33	3.29	2.01	3.26	0.87	1.96
Trace Elements (ppm)							
Ni	36.57	47.17	40.83	10.31	61.94	29.83	84.02
Cr	83.05	47.77	54.90	17.14	69.07	34.49	125.19
V	53.22	113.67	96.03	25.07	115.06	84.14	213.15
Ga	19.62	15.86	16.15	19.03	17.05	21.01	16.35
Cu	13.77	25.17	21.80	7.73	20.22	12.09	35.76
Zn	54.41	55.79	58.96	85.72	73.63	112.38	81.85
La	24.13	60.23	55.51	53.28	83.14	74.61	22.11
Ce	44.76	128.49	113.00	88.01	159.65	130.45	45.70
Pr	5.23	15.57	13.72	10.37	18.12	15.50	5.81
Nd	19.22	58.55	50.39	37.37	64.74	54.12	24.03
Sm	3.60	9.27	8.15	5.77	9.82	7.54	5.14
Eu	1.00	2.62	1.95	1.53	2.58	2.16	1.78
Gd	2.84	6.37	5.89	3.90	6.65	4.46	5.11
Tb	0.40	0.85	0.84	0.49	0.91	0.53	0.82
Dy	2.25	4.63	4.75	2.66	4.81	2.50	4.95
Ho	0.46	0.89	0.94	0.52	0.91	0.43	0.99
Er	1.26	2.31	2.52	1.38	2.44	1.00	2.63
Tm	0.19	0.33	0.38	0.20	0.34	0.13	0.37
Yb	1.21	2.15	2.47	1.28	2.15	0.73	2.21
Lu	0.19	0.34	0.39	0.19	0.33	0.11	0.33
Ba	1068.00	2637.00	2043.00	2522.00	2711.00	2428.00	782.00
Th	6.94	7.28	12.41	11.84	12.96	8.93	2.33
Nb	7.25	89.29	85.34	8.60	56.42	9.90	19.79
Y	12.83	22.75	24.67	14.09	23.84	11.89	24.34
Hf	3.38	6.12	5.29	4.47	5.47	3.92	2.81
Ta	0.49	5.58	5.90	0.54	3.38	0.47	1.16
U	3.04	1.98	3.71	2.46	2.91	1.50	0.62
Pb	20.94	6.12	15.75	25.94	11.89	14.72	2.76
Rb	98.50	192.70	116.30	103.30	77.30	46.70	23.30
Cs	3.30	4.52	5.95	2.99	2.54	4.83	10.95
Sr	578.00	1564.00	868.00	705.00	1359.00	1435.00	482.00
Sc	7.60	17.10	13.50	5.10	14.40	7.80	27.70
Zr	125.00	292.00	226.00	175.00	237.00	163.00	113.00

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 $Fe2^{+}$. LOI is loss on ignition. Datum used for sample coordinates is World Geodetic Survey 1984 (WGS84).

Table 2. U-Pb zircon ages

Sample	Map Unit	Latitude	Longitude	Age (Ma)	2σ
ES-04	Tbai	46.6587	-112.7151	29.95	0.17
ES-06	Tr	46.7135	-112.7356	46.01	0.23
ES-05	Tda	46.6657	-112.7387	47.4	0.19
ES-01	Tdapi	46.6402	-112.7169	51.46	0.25

All samples analyzed by LA-ICPMS at the University of California, Santa Barbara. Datum used for sample coordinates is World Geodetic Survey 1984 (WGS84).

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Geologic Map of the Gravely Mountain 7.5' Quadrangle Powell County, Montana

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2017