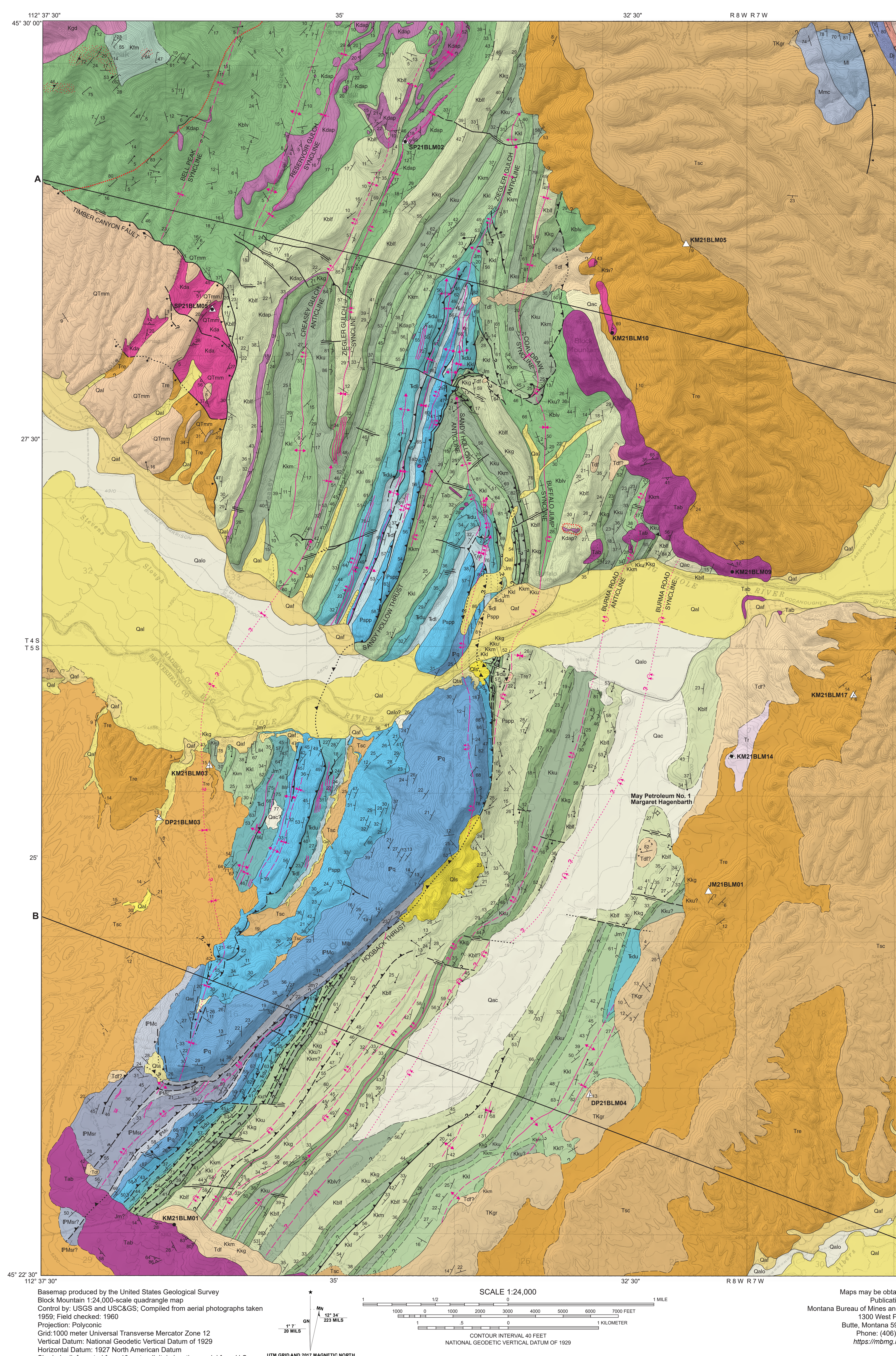


Basemap produced by the United States Geological Survey
Block Mountain 1:24,000-scale quadrangle map
Control by: USGS and USC&GS; Compiled from aerial photographs taken 1959; Field checked: 1960
Projection: Polyconic
Grid:1000 meter Universal Transverse Mercator Zone 12
Vertical Datum: National Geodetic 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.

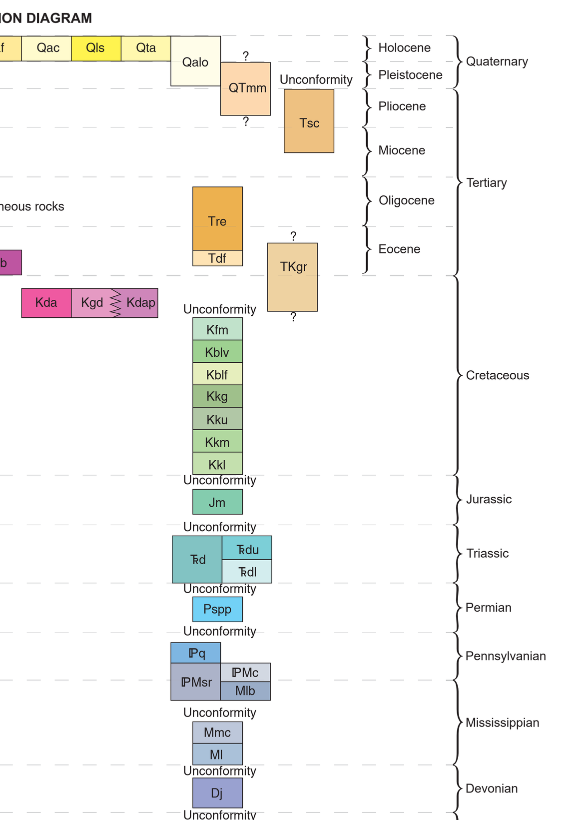
UTM GRID AND 2017 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000

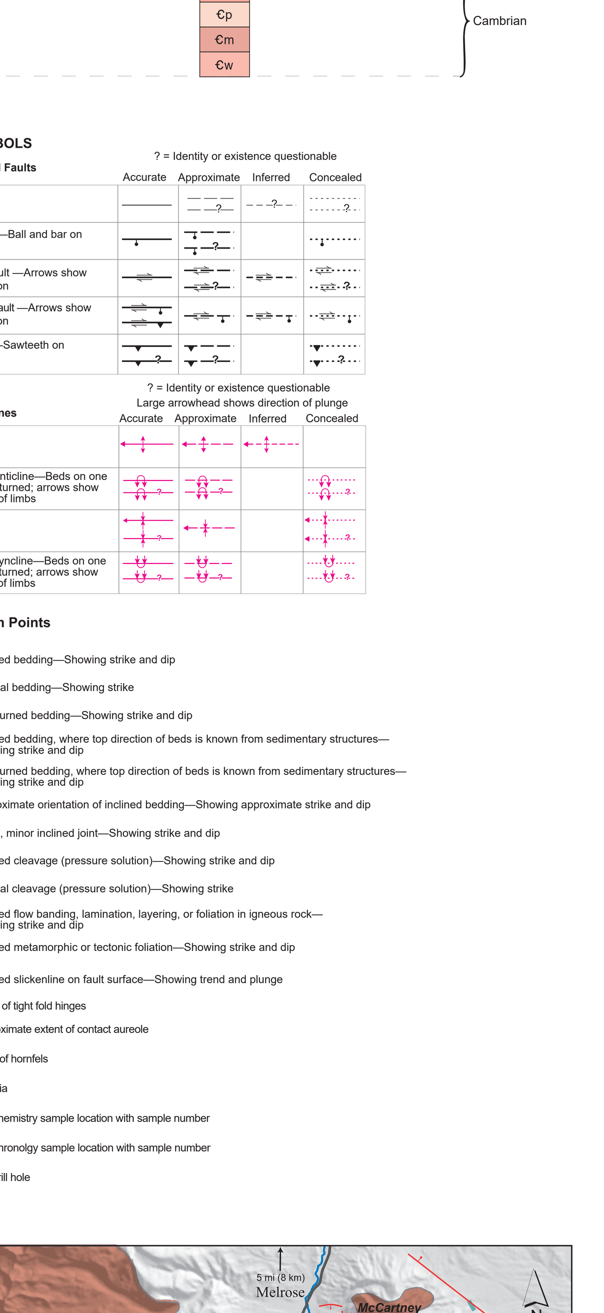
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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
https://mbmg.mtech.edu

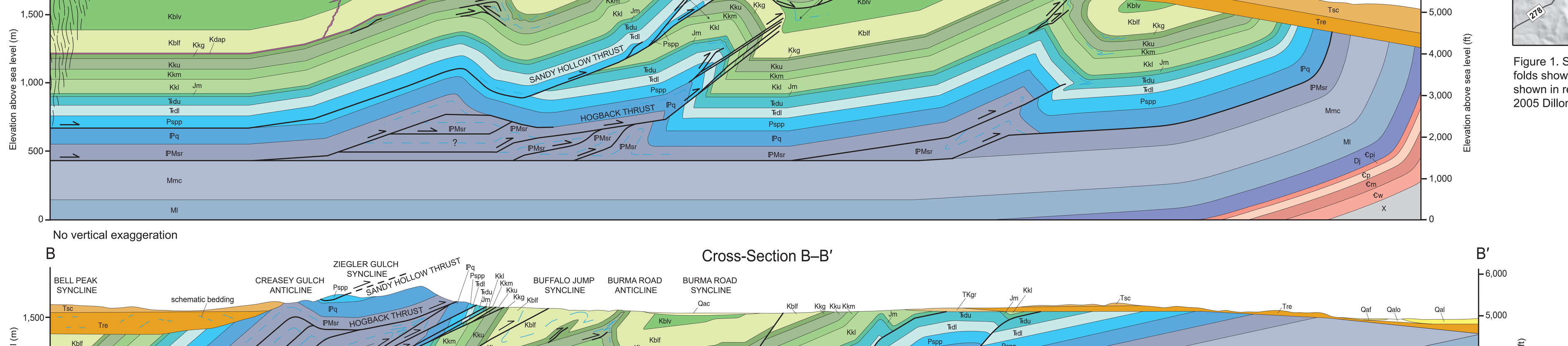
CORRELATION DIAGRAM



MAP SYMBOLS

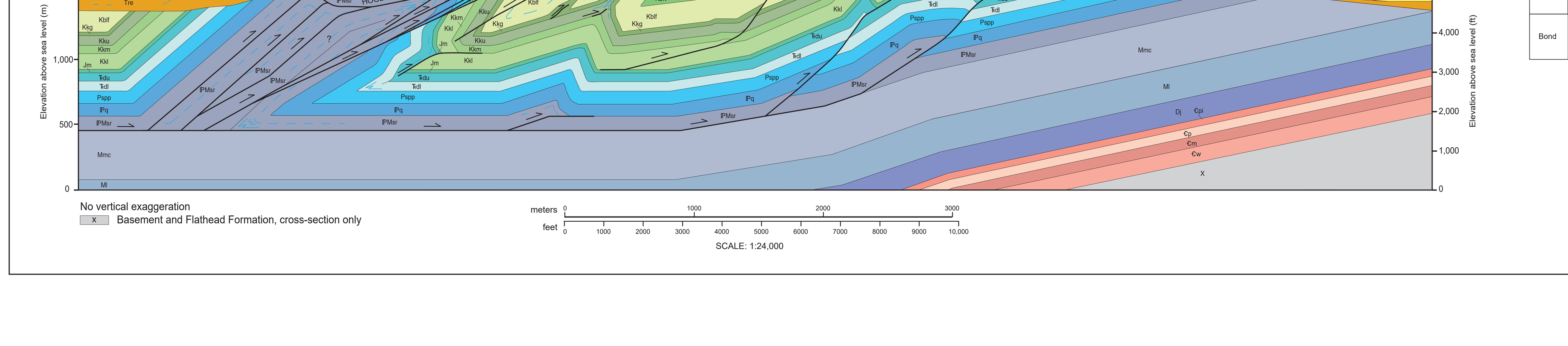


Cross-Section A–A′



No vertical exaggeration

Cross-Section B–B′



No vertical exaggeration
X Basement and Flathead Formation, 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

INTRODUCTION

The Block Mountain 7.5′ quadrangle straddles Beaverhead and Madison Counties, approximately 20 km north of Dillon, MT, between McCartney Mountain (referred to as McCarthy Mountain before about 1984) and the Beaverhead River (fig. 1). Moderate elevations, ranging from 1,466 to 2,397 m (4,810 to 7,865 ft), and a dry climate result in sparse vegetation and great exposure throughout much of the quadrangle. Dissected by the Big Hole River, the exhumed folds and thrust faults of the Sandy Hollow uplift (fig. 1) have been visited by countless university field camps since at least the early 1960s. The impressive folds and thrusts of the Sandy Hollow uplift define the leading edge of the McCartney Mountain salient (fig. 1; Brumbaugh, 1973), which has been interpreted by many as a zone of overlap between thin- and thick-skinned structures of the Cordilleran fold-thrust belt (e.g. Brumbaugh, 1973; Brandon, 1984).

PREVIOUS MAPPING AND METHODS

Mapping in the "McCarthy" Mountain area began in 1910 by United States Geological Survey (USGS) geologist H.S. Gale, published later by Richards and Pardee (1925, scale 1:62,500). Steuer (1956) measured numerous sections, revised the stratigraphy, and mapped the quadrangle at 1:20,000 scale. A Tertiary mammalian fossil locality (Douglas, 1905) between Buhrer and Creasey Gulches, in the northwestern part of the map, was the focus of several master's theses: Riel (1963, scale 1:15,840 and 1:3,600), Hoffman (1971, scale, 1:48,000), and McHugh (2003, scale 1:6,000). Brumbaugh (1973, scale 1:24,000) and Brandon (1984, scale 1:24,000) included the quadrangle in a larger structural analysis of the McCartney Mountain salient. Air photos annotated by H. Dresser (Brumbaugh and Dresser, 1976) and a seismic profile across the quadrangle by Lopez and Schmidt (1985) informed many studies, including Schmidt and others (1988, scale 1:90,000). Students and instructors of field camps have produced countless unpublished maps and cross-sections of the Sandy Hollow area over the years. We thank Rob Thomas, Celine Beaucamp, Mike Stickney, and Steve Quane for discussions and reviews.

Rock samples collected for U-Pb geochronology were processed at the MBMG mineral separation laboratory. 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) at the University of California, Santa Barbara.

GEOLOGIC SUMMARY

Strata of the Block Mountain quadrangle include mixed siliciclastic and carbonate rocks deposited on the passive margin of North America in the Cambrian to Jurassic. The Paleozoic part of the section is mostly limestone and dolostone, deposited on a shallow marine shelf when the sea inundated Montana. Siliciclastic sediment shed from the continent was deposited near the shoreline during sea-level lowstands. During sea-level highstands, subtidal siliciclastic and carbonate muds and chert were deposited. Phosphate, chert, and many fossil fragments are absent after the Permian–Triassic extinction (Peterson, 1981). In the Jurassic, the thin non-marine Morrison Formation was deposited on the eroded upper part of Triassic strata, marking the end of the passive margin.

The impressive thrust faults and folds of the Sandy Hollow uplift reflect deformation related to the Sevier–Laramide Orogeny, as Andean-style subduction shortened the continental margin. Beginning ca. 135 Ma, the Kootenai Formation was deposited in a flexural foreland basin, with fluvial sediment sourced from the orogenic mountain belt to the west (Rosenblume and others, 2021). The foreland basin was inundated by the Western Interior Seaway in the Albian, during deposition of the Blackleaf Formation (ca. 106 Ma; Gardner and others, 2022; Rosenblume and others, 2022). Shallow emplacement (depths of 1–3 km, 3,000–8,000 ft; Friberg and Vitaliano, 1981) of the McCartney Mountain pluton coincided with deformation, ca. 75 Ma (table 1; Foster and others, 2012). Restoration of the balanced cross-sections that span the quadrangle suggests a minimum shortening of about 20% (2 km, 1.2 mi). Much of this shortening was accommodated on the two largest thrust faults in the quadrangle: the Sandy Hollow and Hogback thrusts. First-order folds of the Sandy Hallow uplift, which are labeled on the map, are likely the surface expression of either fault propagation folds or duplexes that occur at depth. High strain zones within tight fold hinges and near thrust faults contain smaller-scale thrust, fold, and cleavage duplexes, indicating the presence of several additional stratigraphically controlled detachment horizons that separate mechanically distinct units (Parker and Boyer, 2025). At all scales, deformation features and kinematic indicators constrain a top-to-the-ESE sense of slip (fig. 2), above a decollement in the Mississippian to Pennsylvanian Snowcrest Range Group. The apparent shortening direction inferred from local deformation features was rotated clockwise during development of the McCarney Mountain salient, with higher magnitude rotation localized in fault-bound blocks along the Sandy Hollow thrust (Eldredge and Van der Voo, 1988). The thin-skinned McCartney Mountain salient, and the underlying basement, were ultimately folded during southwest-directed back thrusting on the Biltmore Anticline (fig. 1).

The Sandy Hollow uplift and McCartney Mountain pluton were exhumed by the Eocene as mafic to felsic volcanic flows began filling topographic lows ca. 48 Ma (table 1; Fritz and others, 2007). Continued erosion inverted the topography, leaving resistant rocks of Block Mountain, Bell Peak, and the Hogback as topographic highs. The paleotopography of the newly formed intermontane basin was very similar to the modern day, as alluvial fans from adjacent highs merged with fluvial trunk streams and their floodplains (Schwartz and Schwartz, 2013). In the humid Eocene climate (ca. 35 Ma), a host of mammals lived in the brushy to swampy areas along the streams (Hoffman, 1971). Following nondeposition or erosion and a switch to a more arid climate, deposition of the Sixmile Creek Formation started in the Miocene (ca. 10 Ma; table 1). The Timber Canyon fault system (fig. 1) down dropped the western flank of the Sandy Hollow uplift relative to Bell Peak, and may remain active. Ongoing incision by the Big Hole River has carved through the Sandy Hollow uplift, leading to the impressive notch seen today.

UNIT DESCRIPTIONS

Qal **Alluvium (Holocene)**—Unconsolidated, poorly sorted to well-sorted gravel, sand, silt, and clay deposited by modern streams and rivers. Thickness may be as much as 12 m (40 ft) along the Big Hole River, based on logs for domestic groundwater wells in the neighboring Glen quadrangle (Yakovlev, 2019). Unit thickness is unconstrained elsewhere, but is likely greater near the Beaverhead River.

Qaf **Alluvial fan deposit (Holocene)**—Unconsolidated deposits of clay- to cobble-sized angular clasts forming broad, conical fan deposits at drainage mouths. Up to 10 m (33 ft) thick.

Qac **Alluvium and Colluvium (Holocene)**—Dominantly sand, silt, clay, and subordinate gravel locally, deposited on gentle slopes by sheetwash and gravity processes. Thickness generally less than 10 m (33 ft).

Qls **Landslide deposit (Holocene)**—Mass-wasting deposits comprising of unsorted mixtures of clay- to boulder-sized sediment. Includes large, rotated or slumped blocks of bedrock on the eastern side of the Hogback. Color and lithology reflect that of nearby parent rocks and transported surficial material. Variable thickness, typically less than 30 m (100 ft).

Qta **Talus (Holocene)**—Coarse, unconsolidated, angular, locally derived clasts in apron-like deposits below steep slopes near the Hogback. May include rockslide deposits. Variable thickness, generally less than 10 m (33 ft).

Qalo **Alluvium, older than Qal (Holocene and Pleistocene?)**—Unconsolidated, poorly sorted to well-sorted deposits of gravel, sand, silt, and clay deposited by modern streams and rivers that form benches and floodplains at higher elevations than Qal. Up to 10 m (33 ft) thick.

QTmm **Gravel at McCartney Mountain (Pleistocene? or Pliocene?)**—Tan, poorly sorted to sorted, clast-supported pebble to boulder conglomerate with angular to sub-angular clasts. Crude, meter-scale bedding is sometimes graded in clast-supported intervals and reverse graded in matrix-supported intervals, defining crude stacked channels. Vuggy matrix of cryptocrystalline quartz is common, often forming thick rinds on clasts. Clast imbrications, channel orientations, and clast composition suggest a proximal source near McCartney Mountain. Unconformably overlies tilted Cretaceous dacite and Renova Formation, with up to 30° of angularity near Buhrer Gulch. The basal contact cuts down to the south, covering an older scarp of the Timber Canyon normal fault. The top of the unit defines an erosional surface that gently dips away from McCartney Mountain and abuts the Timber Canyon fault at the range front. The alluvial fan deposits were likely contemporaneous with movement on the Timber Canyon fault. Possibly correlative with the Sixmile Creek Formation. Thickness ranges from as little as 3 m (10 ft) to as much as 40 m (130 ft) in the immediate hanging wall of the Timber Canyon normal fault in Buhrer Gulch.

Tsc **Sixmile Creek Formation (Pliocene? to Miocene)**—Multicolored, predominantly well-rounded quartzite cobble to boulder conglomerate, inferred from cobble to boulder lag and slope wash. Top of the unit defines a regional-scale erosional surface (upper sequence-4 unconformity of Hanneman and Wideman, 1991) that can be traced into the neighboring quadrangles. Possibly correlative with the Big Hole River Member based on lithologic similarities (Fritz and Sears, 1993) and sequence stratigraphy of Hanneman and Wideman (1991). A reworked tuff near the basal contact yields a maximum depositional age of 9.8 ± 0.2 Ma (table 1, fig. 3A). Pliocene fossils collected in the neighboring Beaverhead Rock quadrangle (Hoffman, 1971) constrain the depositional age near the upper contact. Thickness is at most about 60 m (200 ft).

Tre **Renova Formation (Oligocene to Eocene)**—White, weakly lithified arkosic siltstone to very fine-grained sandstone with interbedded calcareous nodules; tan pebble to cobble conglomerates with interbedded silty to coarse cross-bedded lithic sandstone; white to gray tuffaceous sandstone with interbedded pebble to cobble conglomerate; and rare light gray, massive, matrix-supported pumice breccia. Highly variable interbedded lithologies are interpreted as floodplain/marsh, fluvial channel, and alluvial fan facies. Rarely crops out, commonly forming recessive, white slopes with popcorn weathering and occasional well-rounded cobbles. Broad channels with subrounded to rounded, predominantly quartzite cobbles, and abundant biotite are typical of the fluvial channel facies. Fossil assemblages suggest an early Chadronian age (latest Eocene, ca. 38–34 Ma) near the upper contact in Burher Gulch (e.g., McHugh, 2003), and at Diamond O Ranch about 0.5 km (0.3 mi) east of the map area near the Beaverhead River (Fostowicz-Frelik and Tabrum, 2009; Korth and Tabrum, 2017). The lower part of the section contains interbedded rhyolite tuffs that yielded U-Pb zircon dates with a weighted mean of 48.1 ± 0.3 Ma (table 1, fig. 3G). Reworked tuffs yield maximum depositional ages of 45.5 ± 0.5 and 46.3 ± 1.0 Ma (table 1, figs. 3E, F). Detrital zircon dates from an interbedded sandstone are entirely Cretaceous and older, consistent with recycled proximal sources (table 1, fig. 3B). Correlative with the Bone Basin Member 2 and Climbing Arrow Member of the Renova Formation (Kuenzi and Fields, 1971; Schwartz and Schwartz, 2013; Vuke, 2020), or sequences 1 and 2 of Hanneman and Wideman (1991). Interbedded tuffs are correlative with the Dillon Volcanic Group, but are too thin to map separately. Thickness is at least 30 m (100 ft) based on measured section at Diamond O Ranch (Hoffman, 1971).

Tdf **Debris flow deposit (Eocene?)**—Predominantly boulder lag that defines a gently dipping erosional surface between ~1,705 m (5,600 ft) and 1,525 m (5,000 ft) elevation. Boulders are commonly ½–1 m (1.6–3.3 ft) up to 3–4 m (10–13 ft) in diameter. Angular to subrounded boulders of resistant lithologies, including well-cemented quartz arenite, quartzite conglomerate, porphyritic andesite, granodiorite, hornfels, and petrified wood. All clast lithologies match bedrock within the map area, suggesting proximal sources. Possibly interbedded with ashy gravels of Renova Formation just south of the Big Hole River. Differentiated from the Sixmile Creek and Renova Formations by its lack of well-rounded quartzite cobbles. Near Block Mountain, the top of the unit defines an erosional surface that dips ~2° toward the southeast, projecting below the adjacent Renova Formation. East of the Hogback and south of the Big Hole River, brecciated and silicified glauconitic sandstone (Shedhorn Formation) and thin-bedded chocolate-brown-weathering lime wackestone (Dinwoody Formation) are tentatively interpreted as Tertiary debris flow deposits. South of the Hogback, boulders rest directly on Eocene basalt, constraining the age of mass-wasting deposits to Eocene or younger age. Thickness is probably less than 5 m (15 ft), perhaps as much as 30 m (100 ft) near Block Mountain. Lower contact is often obscured by slope wash.

Tr **Rhyolite (Eocene)**—Light-gray- to pale-pink-weathering glassy to aphanitic rhyolitic (84.9 wt. % SiO_2, fig. 4) welded tuffs and flows. Platy weathering outcrops with flow foliation and breccias are common. Smoky quartz and rare small (<1 mm) hornblende phenocrysts. Exposed only south of the Big Hole River and east of the Hogback, where a rhyolite tuff yielded U-Pb zircon dates with a weighted mean of 47.1 ± 0.2 Ma (table 1, fig. 3H). Interbedded with the lower Renova Formation. Likely correlative with the Barretts Rhyolite and Tuff of the upper Dillon Volcanic Group, based on stratigraphic position, age, and smoky quartz phenocrysts (Mosolf and others, 2021). Thickness is unknown.

Tab **Andesite and basalt (Eocene)**—Black, red-weathering aphanitic to vesicular andesite to basaltic andesite (57.1–58.2 wt. % SiO_2, fig. 4) with uncommon flow banding. Rare green, orange-weathering olivine phenocrysts. Prominent cliff former with columnar jointing on Block Mountain. Yielded whole-rock K-Ar ages of 47.1 ± 0.9 Ma along Burma Road near Block Mountain, and 44.7 ± 1.1 and 46.1 ± 1.0 Ma at the southern end of the Hogback (Fritz and others, 2007). Likely correlative with the Gallagher Butte Basalt of the Dillon Volcanic Group (Mosolf and others, 2021). Inferred vent near Melrose, Montana (fig. 1; Fritz and others, 2007). Thickness is up to about 90 m (300 ft) at Block Mountain.

TKgr **Gravel and conglomerate (Eocene? to Late Cretaceous)**—Tan to reddish orange, well-lithified quartzite pebble to cobble conglomerate and interbedded medium-grained lithic sandstone. Crude bedding on the meter-scale, with occasional incised channels with crossbedding. Conglomerates are poorly sorted and clast-supported, with subrounded to subangular clasts. Sandstone facies and conglomerate matrix consists of rounded to subrounded, moderately to well-sorted medium sand grains of quartz, and lithics of quartzite and chert. Facies suggest an alluvial depositional environment, with a local provenance near the Hogback. The isolated outcrop in the northeastern corner of the map contains limestone and gneiss clasts, suggesting a proximal source to the immediate southeast. Lower contact is angular unconformity with folded Mesozoic and Paleozoic rocks, although a local fault contact cannot be ruled out for the northernmost outcrop. The maximum depositional age of sample DP21BLM04 (table 1, fig. 3I) makes it unclear whether the unit is correlative with the Beaverhead Group or Tertiary debris-flow deposits that are mapped along strike. Thickness is likely less than 45 m (150 ft).

Kda **Dacite (Late Cretaceous)**—Dark gray, tan-, lavender-, and maroon-weathering dacite (64.2–67.8 wt. % SiO_2, fig. 4). Bright red cliffs of volcanoclastic breccia exposed near Chokecherry Gulch are commonly approximately 10–15 m (30–50 ft) tall, with flow-banded interiors and red, brecciated flow bases. Flow-banded dacite sometimes contains weathered biotite phenocrysts, spherulites, and secondary epidote (?) alteration. Upper unconformable contact with the gravels of McCartney Mountain (unit QTmm) is well exposed in Buhrer Gulch. U-Pb zircon dates give a weighted mean of 75.1 ± 0.4 Ma, with a few inherited Paleoproterozoic and Archean grains (table 1, fig. 3C). Undated dacite near Block Mountain is tentatively correlated based on similar geochemistry (fig. 4). Thickness is at least 30 m (100 ft).

Kgd **Granodiorite (Late Cretaceous)**—Gray, coarse-grained biotite granodiorite with common feldspar and hornblende phenocrysts. Near Bell Peak the intrusive contact is sharp, planar, and steep, cross-cutting flat-lying Blackleaf and Frontier Formations. Part of the McCartney Mountain pluton that yielded a biotite K-Ar apparent age of 74 ± 1 Ma (Brumbaugh and Hendrix, 1981) and a U-Pb zircon date of 74.5 ± 1.1 Ma based on a weighted mean of five concordant zircons (Foster and others, 2012).

Kdap **Dacite porphyry (Late Cretaceous)**—Green to black, porphyritic dacite (64.4 wt. % SiO_2, fig. 4) sills with common hornblende and plagioclase phenocrysts. Sills weather tan to brown, with variable foliation in thinner units and columnar jointing in thicker units. Mapped sills highlight three main complexes: near the basal contact, and above and below the middle contact of the Blackleaf Formation. Sills are folded within the Creasey Gulch anticline and the Reservoir and Zeigler Gulch synclines. Sills interfinger with the ca. 75 Ma McCartney Mountain pluton, suggesting contemporaneous emplacement and a shared source (Gunckel, 1990). U-Pb zircon dates give a weighted mean of 75.0 ± 0.4 Ma, with a few inherited Paleoproterozoic and Archean grains (table 1, fig. 3D). Sills are generally 2–3 m (6.5–10 ft) thick, reaching a maximum thickness of 15 m (50 ft) near the head of Reservoir Gulch.

Kfm **Frontier Formation, metamorphosed (Late Cretaceous)**—Green and gray metamorphosed siltstone and mudstone; salt and pepper, medium- to fine-grained lithic sandstone; and local conglomeratic quartz sandstone. Occurs only on Bell Peak, within the contact aureole of the McCartney Mountain pluton. Lower contact is placed above the uppermost outcrop of red metamorphosed siltstone, based on well-exposed sections near Willow Creek, about 10 km (6 mi) to the southwest, and Rock Creek, about 20 km (12 mi) to the west (Dyman and others, 1994). Upper contact not exposed. Minimum thickness of approximately 130 m (425 ft) on Bell Peak.

Kblv **Blackleaf Formation, Vaughn Member (Late to Early Cretaceous)**—Black and greenish gray to brown mudstone and shale; gray porcellanite with lapilli; and interbedded fine- to coarse-grained feldspathic and lithic sandstones. Mudstone is rarely exposed as massive outcrops with pervasive pencil cleavage. Interbedded sandstone is often tabular on the ½–1 m (1.5–3 ft) scale. Thicker meter-scale sandstone beds define channels in mudstone. Uncommon flat laminations, low-angle and trough crossbedding, mud chips, and ripples. Feldspathic sandstones are generally compositionally immature with medium to coarse, subangular grains, suggesting a volcanic-rich source. Locally metamorphosed to quartzites and hornfels within about 500 m (1,650 ft) of the McCartney Mountain pluton. The upper 400 m (1,310 ft) forms steep slopes on Bell Peak, with abundant porcellanites with flattened accretionary lapilli, graded bedding, and climbing ripples. The lower 180 m (590 ft) erodes to low benches near Reservoir Gulch and includes interbedded shales and sandstones. U-Pb dating of detrital zircons yielded Albian–Cenomanian maximum depositional ages of 96.9 ± 0.3 Ma, from a porcellanite bed located about 210 m (690 ft) below the upper contact near Apex (Zartman and others, 1995) and 107.4 ± 5.0 Ma, from one of the lowest sandstone beds (Gardner and others, 2022). Total thickness is 580 m (1,900 ft) based on measured sections of Steuer (1956), from Reservoir Gulch to Bell Peak, and Dyman and Tysdal (1990), about 10 km (6 mi) to the southwest.

Kblf **Blackleaf Formation, Flood Member (Early Cretaceous)**—Tan, brown- to orange-weathering lithic sandstone with interbedded black to green shale. Salt and pepper lithic sandstones are generally fine- to medium-grained with common bioturbation, ripples, channels, graded beds, low-angle and trough crossbeds, and occasional mud chips. The member is divided into three informal lithologic units, based on outcrop pattern: an upper cliff-forming sandstone with massive 1- to 10 m-scale (3–30 ft thick) bedding, and a sharp upper contact above a quartz-cemented quartz arenite that forms a prominent dip slope throughout much of the map area; a middle recessive shale with occasional isolated lenses of sandstone outcrop; and a lower, cliff-forming sandstone unit with rare black shale interbeds near the basal gradational contact with the underlying Kootenai Formation. U-Pb detrital zircon dating yielded Albian maximum depositional ages of 106.2 ± 1.2 Ma, from the upper part of the lower sandstone unit (Rosenblume and others, 2021), and 105.8 ± 0.5 Ma, near the upper contact (Gardner and others, 2022). Measured thickness of 785 m (80 ft) in Buhrer Gulch (Rosenblume, 2021).

Kkg **Kootenai Formation, gastropod limestone member, informal (Early Cretaceous)**—Light gray fossiliferous wackestone and packstone with shaly partings and abundant gastropods. Tabular 1/3- to 2-m-thick (1–6 ft) beds commonly form low cliff bands. Fossiliferous beds sometimes fine upward, with mudcracked tops. In addition to gastropods, grazing traces, bivalves, ooids, and peloids are common, particularly in the upper part. Upper contact, above the highest limestone bed, is most often sharp but can be gradational over up to 10 m (30 ft) with overlying black shale or sandstone of the Blackleaf Formation. U-Pb dating of detrital zircon yielded an Albian maximum depositional age of 111.5 ± 3.0 Ma, at the top of the unit in Ziegler Gulch (Finzel and Rosenblume, 2021). Measured thickness of 25 m (80 ft) in Ziegler Gulch (Rosenblume, 2021) and 36 m (118 ft) in Sandy Hollow (Hendrix and Porter, 1980).

Kku **Kootenai Formation, upper clastic member, informal (Early Cretaceous)**—Red to gray siltstone and mudstone with interbedded tan to gray, brown–-orange-weathering cross-bedded salt and pepper lithic sandstone. Silt and mudstone rarely outcrop, mostly forming red recessive slopes with uncommon outcrops of flaggy, medium- to coarse-grained sandstone. Upper contact, placed below the first limestone bed of the gastropod limestone member. U-Pb dating of detrital zircon yielded an Albian maximum depositional age of 113.2 ± 0.8 Ma from the lower part of the unit in Ziegler Gulch (Finzel and Rosenblume, 2021). Measured thickness of 75 m (245 ft) in Ziegler Gulch (Rosenblume and others, 2021), but often structurally thickened near fold hinges.

Kkm **Kootenai Formation, middle limestone member, informal (Early Cretaceous)**—Gray lime wackestone with uncommon black chert nodules and tan- to yellow-weathering dolo- and lime mudstone. Tabular, about 20-cm- to ½-m-thick (8–20 in) beds of yellow-weathering dolo-mudstone mark the base. Upper contact placed above the highest limestone bed, which is typically massive to tabular on the ½ to 1 m scale. U-Pb dating of detrital zircon yielded an Albian maximum depositional age of 114.9 ± 1.8 Ma, from the upper part of the unit in Ziegler Gulch (Finzel and Rosenblume, 2021). Measured thickness of 65 m (215 ft) in Ziegler Gulch (Rosenblume and others, 2021).

Kkl **Kootenai Formation, lower clastic member, informal (Early Cretaceous)**—Tan to gray, brown–orange-weathering medium- to coarse-grained salt and pepper lithic sandstone; quartzite pebble to cobble conglomerate; and interbedded red, gray, and purple siltstone and mudstone. Crops out as bands of sandstone with recessive, brick-red silt- and mudstone intervals. Gradational upper contact is placed at the base of the overlying yellow dolo-mudstone marker bed, above a recessive, partly calcareous purple to gray mudstone. Channels, crossbedding, ripples, and mudcracks are common. The basal conglomerate forms prominent, massively bedded cliffs with well-rounded quartzite cobbles and coarse-grained salt and pepper lithic sandstone. Basal conglomerate fills wide, low-relief channels, varying laterally from 0 to about 10 m (30 ft) thick. U-Pb dating of detrital zircon yielded an Albian maximum depositional age of 135.6 ± 1.0 Ma, for a sandstone just above the basal conglomerate (Finzel and Rosenblume, 2021). Measured thickness of 110 m (360 ft) in Ziegler Gulch (Rosenblume and others, 2021).

Jm **Morrison Formation (Upper Jurassic)**—Green, gray, and brown siltstone and mudstone with rare calcareous mudstone, ooid grainstone, and edgewise conglomerates. Siltstone contains coarse subangular chert and quartz sand suspended in silty matrix, sometimes with nodular horizons of gray, calcareous cement. Forms green, recessive swales, often covered by conglomerate boulders of the basal Kootenai Formation. Best exposed on saddles where the overlying Kootenai has been completely eroded. Age is Tithonian (152–149 Ma) according to regional chronostratigraphic framework of Maidment and Muxworthy (2019). Contacts form local detachment horizons, accommodating flexural slip (Parker and Boyer, 2025). Thickness of about 25 m (80 ft) based on measured sections by Steuer (1956) and Smith and others (2006).

Ŧd **Dinwoody Formation, undivided (Early Triassic)**—Chocolate-brown-weathering lime wackestone with yellow to orange siltstone interbeds. Tabular-bedded wackestone with wavy laminations forms prominent outcrop bands, ranging in thickness from 1/3 to 2 m (1 to 6 ft). Flat-laminated siltstone with centimeter-scale bedding forms recessive slopes. Common Lingula fossils suggest an Early Triassic (Griesbachian) age (Rodland and Bottjer, 2001). Thickness is approximately 140 m (460 ft) based on measured section by Steuer (1956).

Ŧdu **Dinwoody Formation, upper (Early Triassic)**—Chocolate-brown-weathering lime wackestone with yellow to orange siltstone interbeds, black shale, and mudstone. Characteristic tabular bedding ranging from 1/3 to 2 m (1 to 6 ft) thick. Wavy laminations, cross-bedding, and ripples common. Commonly weathers to grainy surface texture. Sharp upper contact often forms a dip slope, above the highest limestone bed. Upper part forms sporadic outcrop bands of platy limestone and recessive siltstone and mudstone intervals. Middle part forms low fins of tabular-bedded limestone and recessive slopes of shale and siltstone. Lower part forms prominent cliffs, with sharp undercut bases of thick, tabular-bedded limestone beds. Thickness is approximately 65 m (215 ft) based on measured section by Steuer (1956).

Ŧdl **Dinwoody Formation, lower (Early Triassic)**—Tan, yellow to brown siltstone, shale, very fine-grained sandstone, and minor brown lime wackestone interbeds. Flat-laminated siltstone with centimeter-scale bedding is common; forms recessive slopes with rare subcrops of interbedded 10- to 20-cm-thick tabular limestone beds. Contains gypsum stringers and lenses. Upper contact is gradational over about 2 m (6 ft), placed at the base of the first cliff- forming limestone bed. Thickness is approximately 75 m (245 ft) based on measured section by Steuer (1956).

Pspp **Shedhorn, Phosphoria, and Park City Formations, undivided (Permian)**—

Shedhorn Formation—Tan to white, massive to thin-bedded, well-sorted fine-grained quartz arenite with glauconite and interbedded chert. Presence of glauconite and tabular bedding differentiates the Shedhorn from the Quadrant Formation. Upper contact is placed above the uppermost cliff-forming sandstone or chert outcrop. Thickness is approximately 20 m (65 ft) based on measured sections on the northwestern flank of the Hogback (Steuer, 1956; Cressman and Swanson, 1964).

Phosphoria Formation—Black to tan thick-bedded chert that grades upwards into thin-bedded chert. Vertical chert cylinders with diameters up to 10 cm are found near the middle-upper part; interpreted as either large burrows (*Skolithos grandis* of Andersson and Sauvagnat, 1998) or *in situ* sponges (Moynihan, 2018). A sandstone marker bed occurs just above the rarely exposed phosphorite unit at the base. Thickness is approximately 25 m (80 ft), based on measured sections on the northwestern flank of the Hogback (Steuer, 1956; Cressman and Swanson, 1964).

Park City Formation—Bleached-white dolo-mudstone, with muddy or sandy partings and tabular beds up to 2–3 m (6–10 ft) thick. Upper contact is gradational. Basal contact is marked by a red orange fine-grained sandstone with calcareous cement and about 1/2-m-thick (1.5 ft) bedding. Thickness is approximately 50 m (160 ft), based on measured sections on the northwestern flank of the Hogback (Steuer, 1956; Cressman and Swanson, 1964). Not exposed in the hanging wall of the Sandy Hollow thrust, north of the Big Hole River.

ℙq **Quadrant Formation (Pennsylvanian)**—White to light tan, tan- to brown-weathering vitreous quartz arenite with quartz cement. Massive bedding on the 1 to 10 m (6 to10 ft) scale, with high-angle crossbedding and uncommon flat laminations. Well-sorted fine- to medium-grained quartz sand grains are often indistinguishable from quartz cement. Forms blocky cliffs and talus slopes. Weathered surfaces are often dark brown with a metallic luster, similar to desert varnish. Upper contact is sharp, placed above the prominent dip slope that defines the Hogback. Apparent thickness of approximately 115 m (375 ft) near the Hogback.

ℙMsr **Snowcrest Range Group, undivided (Early Pennsylvanian to Late Mississippian)**—Includes Conover Ranch, Lombard, and Kibbey Formations. Exposed only on the southern flanks of the Hogback. Previously mapped as Amsden Formation (e.g., Steuer, 1956; Brumbaugh, 1973; Brandon, 1984). The upper part consists of the Conover Ranch Formation, which forms red-weathering slopes and swales of fine-grained siliciclastic rocks. The middle part is the Lombard Formation, forming low cliffs of tabular bedded limestone. The lower part consists of the Kibbey Formation, which is poorly exposed fine-grained sandstone and chippy mudstone. Gradational upper contact of Snowcrest Range Group is placed at the base of the lowest cliff-forming quartzite bed. Total thickness of about 100 m (330 ft) based on apparent thicknesses near the Hogback.

ℙMc **Conover Ranch Formation (Early Pennsylvanian to Late Mississippian)**—Tan dolostones, red-weathering fine-grained sandstone and siltstone, and minor limestone conglomerate. Typically forms red-weathering slopes and swales with uncommon float of limestone conglomerate. Dolostone resembles desert storm camouflage, with graded beds and millimeter-scale laminations in tabular beds. Conodonts and available marine fossils suggest a Late Mississippian to early Pennsylvanian age (Chesterian to early Morrowan; Sando and Sandburg, 1985; Wardlaw and Pecora, 1985). Thickness is about 15 m (50 ft).

Mlb **Lombard Formation (Late Mississippian)**—Chocolate brown to gray and red fossiliferous tabular-bedded dolo- and lime mudstones, and lime wackestone with silty partings. Upper part contains massive beds with chert nodules; lower part contains thin-bedded tabular lime mudstone, especially near the base. Conodonts and available marine fossils suggest a Late Mississippian age (Meramecian to Chesterian; Sando and Sandburg, 1985; Wardlaw and Pecora, 1985). Thickness is about 75 m (245 ft).

Mmc **Mission Canyon Formation (Mississippian)**—Light gray, thick-bedded, fossiliferous, cliff-forming limestone with irregular chert bands; local solution breccia zones in the upper part. Thickness is about 360 m (1,190 ft; McDonald and others, 2012).

Ml **Lodgepole Formation (Mississippian)**—Gray, fossiliferous, thin-bedded, slope-forming limestone. The thick basal Cottonwood Canyon Member is a dark shale and siltstone. Thickness is about 290 m (950 ft; McDonald and others, 2012).

Dj **Jefferson Formation (Devonian)**—Light brown to black petroliferous dolomite; thick- to thin-bedded. Locally laminated and shaly, with solution breccia. Thickness 184 m (604 ft; Yakovlev, 2022).

Ꞓpi **Pilgrim Formation (Cambrian)**—Light gray, fine- to medium-grained crystalline, medium- to thick-bedded dolostone; light gray to medium gray, sandy dolostone (O'Neill and others, 1996). Locally vuggy, potentially due to dissolution. Thickness approximately 40 m (130 ft; Yakovlev, 2022).

Ꞓp **Park Formation (Cambrian)**—Pale olive to grayish green finely micaceous fissile shale; minor thin-bedded yellowish brown medium-grained dolostone; and yellowish gray, thinly bedded, platy calcareous fine-grained sandstone, siltstone, and mudstone (O'Neill and others, 1996). Forms topographic lows within the Cambrian section and does not crop out, but can be inferred from float. Thickness approximately 70 m (230 ft; Yakovlev, 2022).

Ꞓm **Meagher Formation (Cambrian)**—Dark to medium gray and tan brown fine- to medium-grained limestone, dolomitic limestone, and dolostone. Locally mottled yellowish gray, light gray, pink, or red (O'Neill and others, 1996). Locally contains thin beds of conglomerate with 1 cm (½ in) diameter clasts. Distinguished from Pilgrim Formation based on its darker gray coloration. Thickness approximately 90 m (295 ft; Yakovlev, 2022).

Ꞓw **Wolsey Formation (Cambrian)**—Olive green, gray–red, and red–brown micaceous and glauconitic siltstone; olive green fissile micaceous shale; gray–red and yellow–gray argillaceous fine-grained platy sandstone and medium gray, fine-grained limestone. Lower part contains iron-rich glauconitic sandstone and deep red pelletal hematite layers (O'Neill and others, 1996). Forms topographic lows within the Cambrian section and does not crop out. Thickness approximately 120 m (394 ft; Yakovlev, 2022).

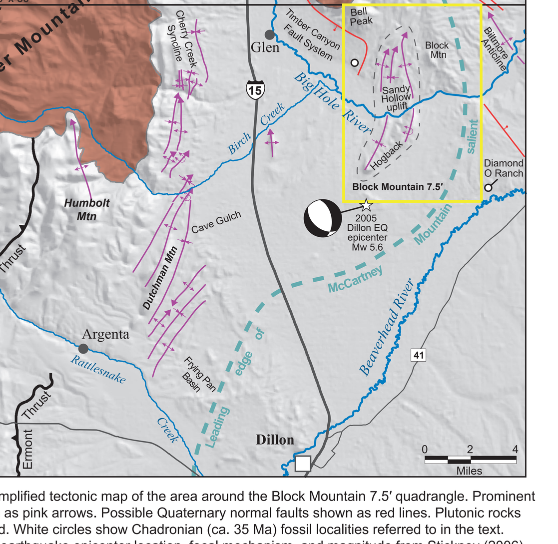
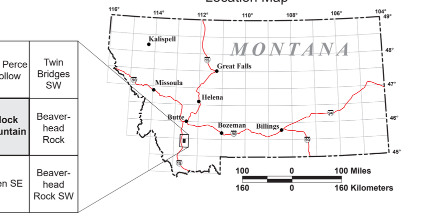


Figure 1. Simplified tectonic map of the area around the Block Mountain 7.5′ quadrangle. Prominent folds shown as pink arrows. Possible Quaternary normal faults shown as red lines. Plutonic rocks shown in red. White circles show Chadronian (ca. 35 Ma) fossil localities referred to in the text. 2005 Dillon earthquake epicenter location, focal mechanism, and magnitude from Stickney (2006).

Location Map



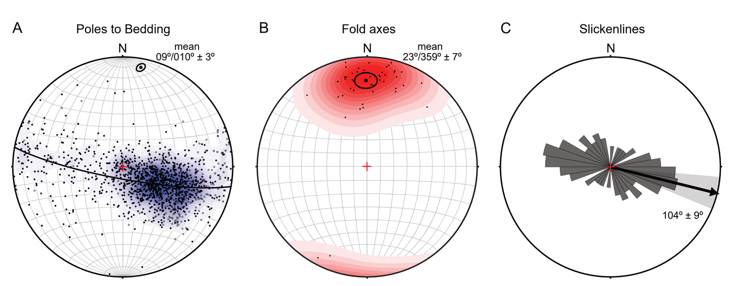


Figure 2. Lower hemisphere equal-area stereographic projections and rose diagram showing orientations of deformation features within Paleozoic and Mesozoic rocks within the map area. Shading denotes Kamb contouring at 2σ-uncertainty envelopes. (A) Poles to bedding (filled dots) and overturned bedding (hollow dots), with calculated best fit girdle and fold hinge and uncertainty labeled. (B) Fold axes measured in the field, with calculated mean fold hinge and uncertainty labeled. (C) Rose diagram showing trend of slickenlines on folded bedding and thrust fault planes. Arrow shows mean vector and uncertainty envelope. Data are treated as axes, with 10° bins.

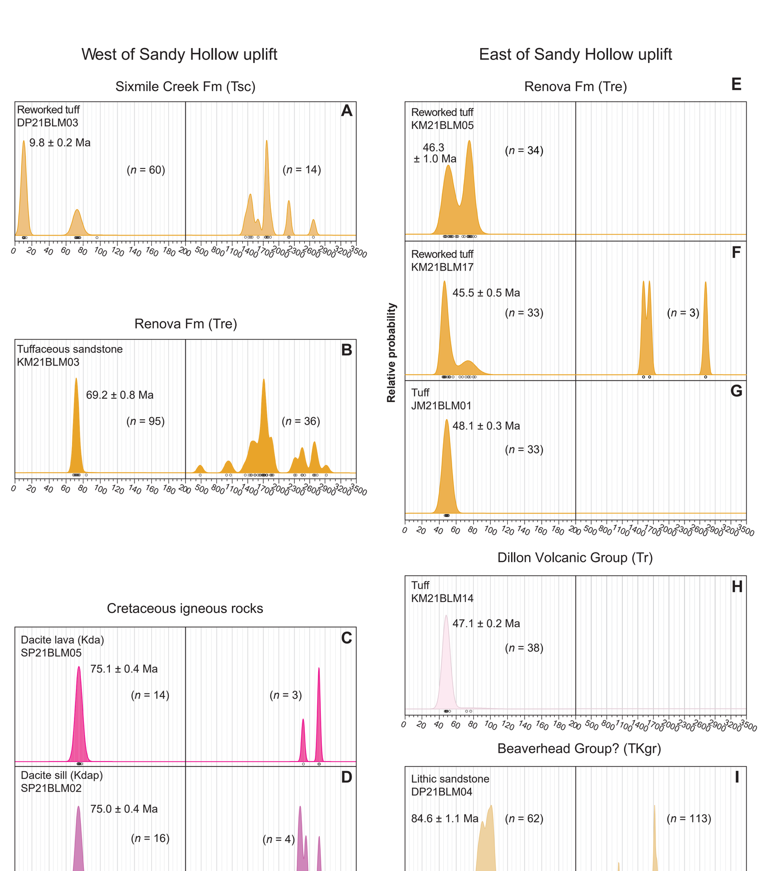


Figure 3. Kernal density estimate (KDE) plots of the ^{207}Pb corrected $^{206}Pb/^{238}U$ (<1,400 Ma) and $^{207}Pb/^{206}Pb$ (>1,400 Ma) zircon ages from volcanic and sedimentary rock samples. Zircon ages from Tertiary rocks (A–B) and Cretaceous igneous rocks (C–D) west of the Sandy Hollow uplift, and Tertiary rocks east of the Sandy Hollow uplift (E–I). Samples arranged from top to bottom in relative stratigraphic order. Bandwidths and bin widths of 5 m.y. were used for KDE plots between 0 and 200 Ma; 10 m.y. and 50 m.y. were used, respectively, for KDE plots between 200 and 3,500 Ma. Circles show individual age analyses.

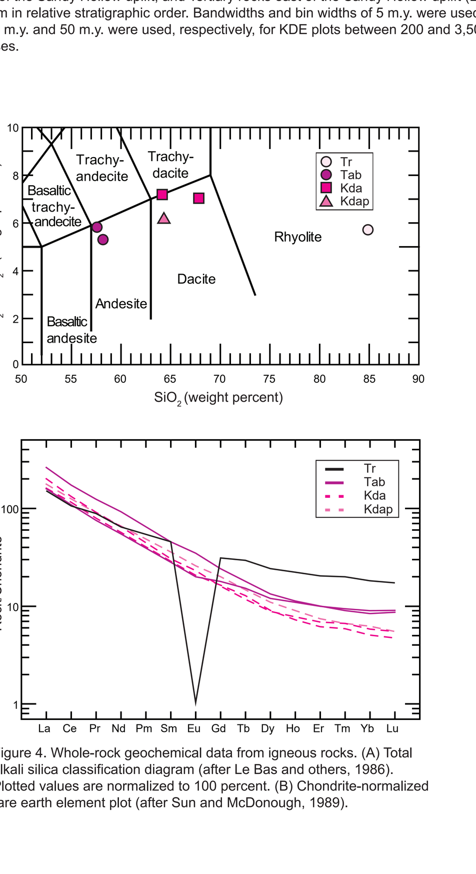


Figure 4. Whole-rock geochemical data from igneous rocks. (A) Total alkali silica classification diagram (after Le Bas and others, 1986). Plotted values are normalized to 100 percent. (B) Chondrite-normalized rare earth element plot (after Sun and McDonough, 1989).

Table 1. U-Pb zircon geochronology.

Sample	Lithology	Unit	Latitude (°N)	Longitude (°W)	No. of spot analyses[a]	Age (Ma)	Interpretation Type	2σ	MSWD
DP21BLM03	Reworked tuff	Tsc	45.421	-112.609	3	9.8	MDA	0.2	0.7
KM21BLM17	Reworked tuff	Tre	45.433	-112.511	3	45.5	MDA	0.5	2.5
KM21BLM05	Reworked tuff	Tre	45.478	-112.535	3	46.3	MDA	*1.0	3.5
KM21BLM14	Rhyolite tuff	Tr	45.427	-112.528	35	47.1	WM	0.2	0.9
JM21BLM01	Rhyolite tuff	Tre	45.413	-112.532	33	48.1	WM	*0.3	2.5
KM21BLM03	Tuffaceous sandstone	Tre	45.426	-112.602	3	69.2	MDA	0.8	2.0
SP21BLM02	Dacite sill	Kdap	45.488	-112.575	15	75.0	WM	0.4	1.0
SP21BLM05	Dacite lava	Kda	45.471	-112.602	14	75.1	WM	0.4	1.0
DP21BLM04	Lithic sandstone	TKgr	45.393	-112.548	3	84.6	MDA	1.1	0.4

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; WM is weighted mean; MDA is maximum depositional age. Zircon separates were prepared at MBMG and analyzed by LA-ICPMS at the University of Canifornia, Santa Barbara.
Latitudes and longitudes are in the 1984 World Geodetic Survey (WGS84) datum.
Three youngest concordant grains were used to calculate maximum depositional ages.
[a]Number of spot analyses used to calculated weighted mean age.
*Uncertainties that take into account overdispersion.

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Geologic Map 115

Geologic Map of the Block Mountain 7.5′ Quadrangle, Southwest Montana

Stuart D. Parker, David M. Pearson, and Catherine McDonald

2026

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