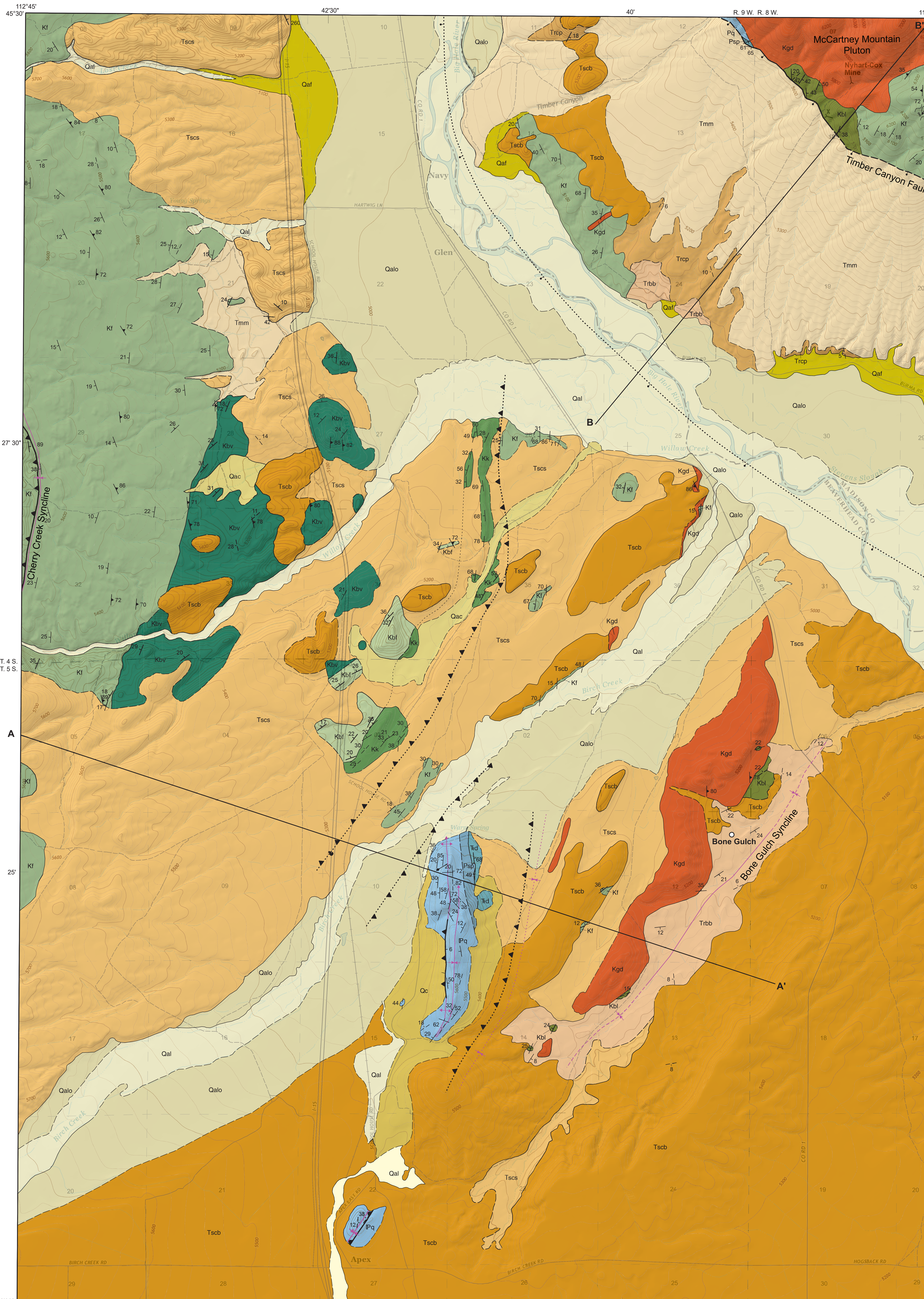


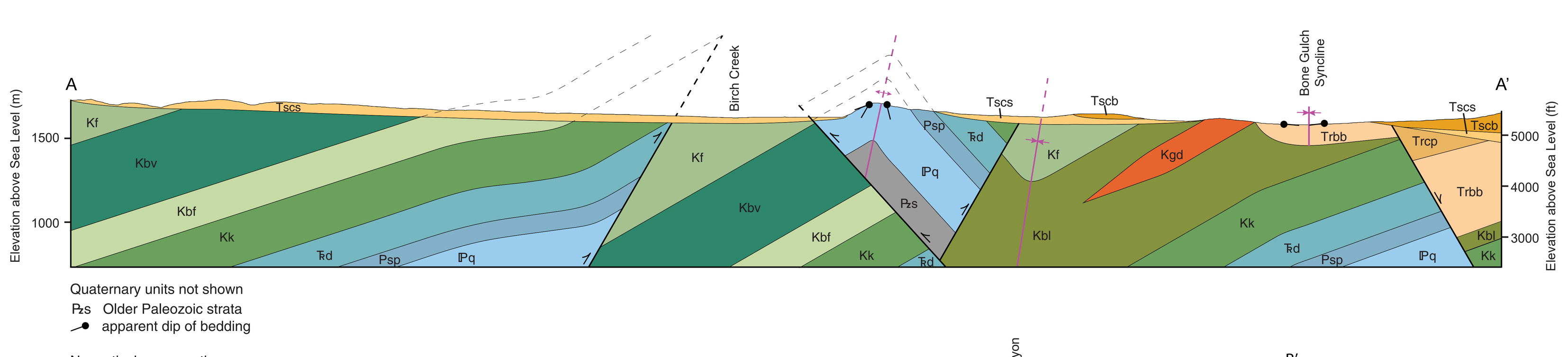
Base map produced from U.S. Geological Survey Topo Combined Vector Product
Shaded relief created from the 10 meter digital elevation model of the U.S. Geological Survey National Elevation Dataset
Projection: Montana State Plane FIPS 2500
Datum: North American Datum of 1983 (NAD 83)

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

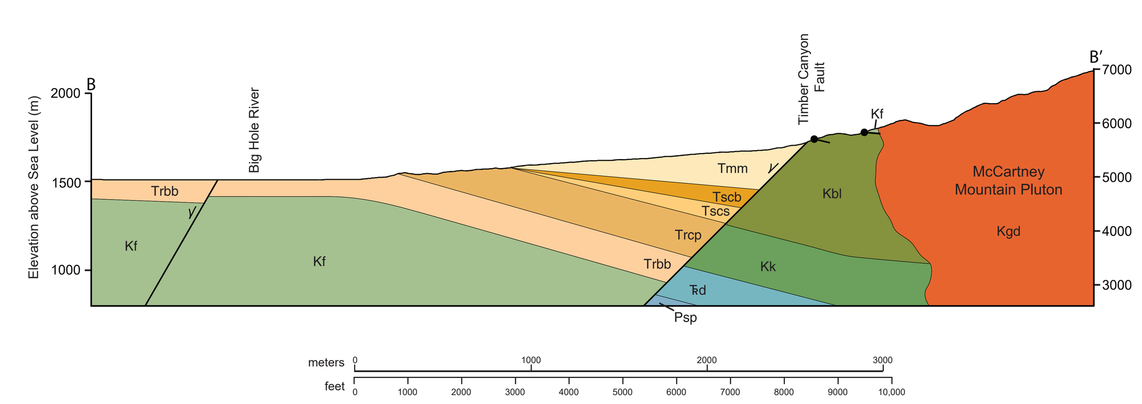
UTM GRID AND 2017 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

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

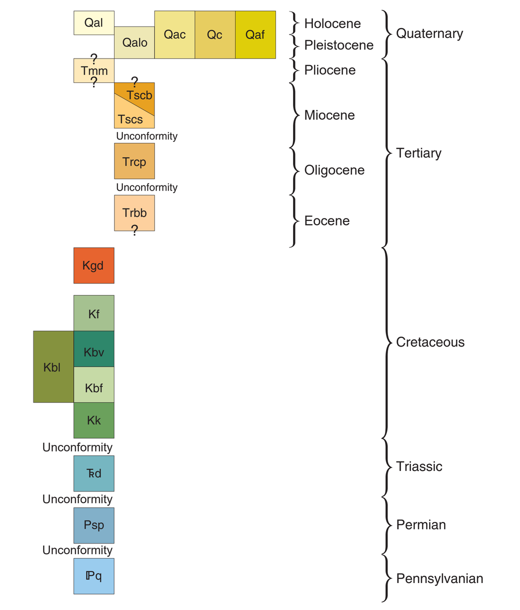


Quaternary units not shown
Pzs Older Paleozoic strata
apparent dip of bedding

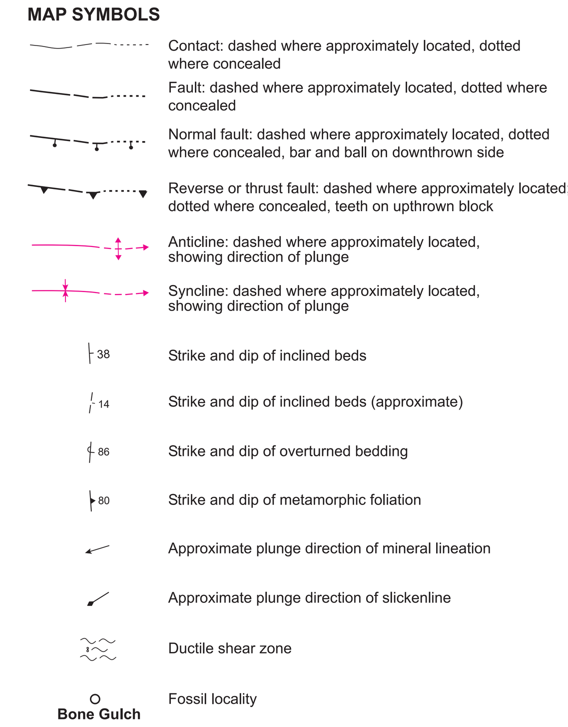
No vertical exaggeration



CORRELATION DIAGRAM



MAP SYMBOLS



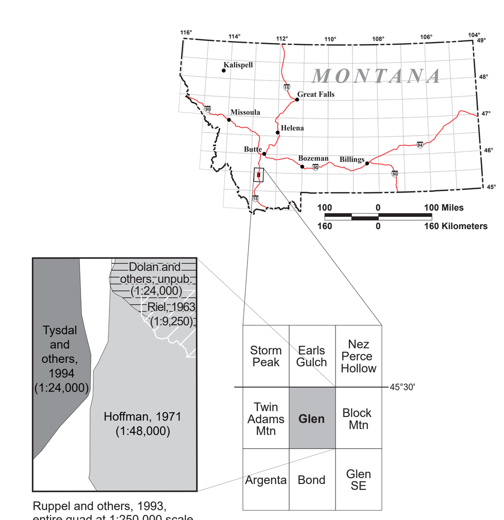


Figure 2. Previous mapping and location map.

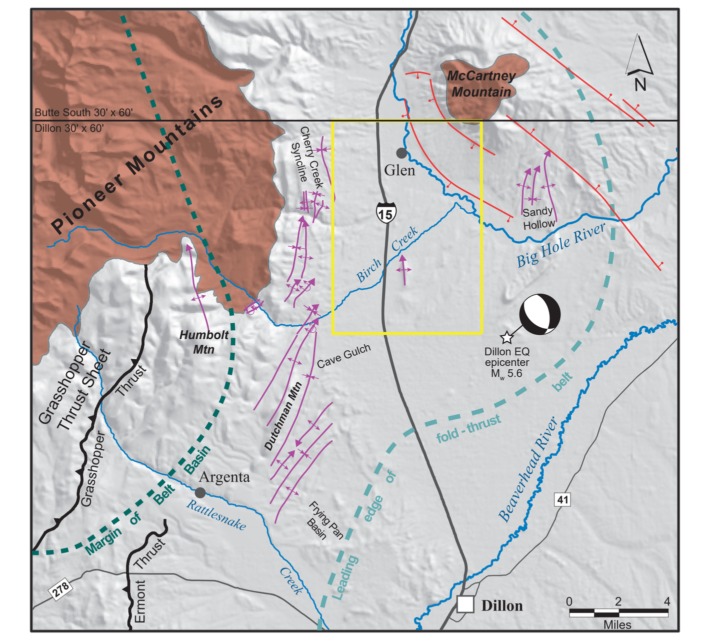


Figure 1. Simplified tectonic map of the area around the Glen 7.5' quadrangle. Prominent folds shown as pink arrows. Quaternary normal faults shown as red lines. Red areas show locations of the Pioneer Batholith and McCartney Mountain pluton.

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG), in conjunction with the STATEMAP advisory committee, selected the Glen 7.5' quadrangle in southwest Montana for detailed mapping as part of the MBMG's on going effort to complete the Dillon 30' x 60' (1:100,000 scale) geologic map. The Glen 7.5' quadrangle is located north of Dillon, Montana, to the east of the Pioneer Mountains, and includes the southwestern portion of McCartney Mountain (fig. 1). A key goal of the mapping was to identify potential Quaternary normal faults that could have been associated with the 2005 M_w 5.6 Dillon earthquake, whose epicenter lay just south of the quadrangle. An additional goal was to reevaluate the Tertiary stratigraphy in the quadrangle using new interpretations developed by the MBMG in the process of drafting the Butte North and Butte South 30' x 60' quadrangles to the north (McDonald and others, 2012; Scarberry and others, 2019).

PREVIOUS MAPPING

The Glen 7.5' quadrangle is included in small-scale mapping by Ruppel and others (1993, scale 1:250,000). Large-scale mapping includes Hoffman (1971, scale 1:48,000), and Tysdal and others (1994, scale 1:24,000), whose work focused on regional paleontology and stratigraphy, respectively. Additional large-scale mapping was performed by Riel (1963, 1:9,250), to locate sites for paleontological investigations, and by Dolan and others, (unpublished, 1:24,000) as part of a 2017 EDMAP project at the University of Montana. The extent of previous mapping is shown on figure 2.

GEOLOGIC SUMMARY

The Glen quadrangle is dominated by Miocene to Pliocene deposits of the Sixmile Creek Formation. Paleozoic through Cretaceous strata primarily crop out as monadnocks (inselbergs) above Tertiary deposits. These older strata are better exposed in the adjacent Block Mountain and Twin Adams Mountain quadrangles to the immediate east and west, respectively. The McCartney Mountain pluton is exposed in the northeast corner of the quadrangle.

The oldest rocks exposed in the quadrangle are associated with the Pennsylvanian Quadrant Formation. The Quadrant Formation primarily outcrops in a northwards-trending anticline and syncline pair found in the southern half of the map area. Small outcrops of the Permian Phosporia and Shedhorn Formations, as well as the Early Triassic Dinwoody Formations, are present on the flanks of this fold. The Early Triassic Woodside Formation and Late Jurassic Morrison formation are either missing due to non-deposition, or not exposed in the Glen quadrangle. Rocks of Middle Triassic through early Late Jurassic age are not present in southwest Montana. Their absence reflects a shift in the tectonic setting of western North America from a continental shelf to an actively subsiding foreland basin (Gibson, 2007).

Cretaceous strata of the Kootenai, Blackleaf, and Frontier Formations dominate bedrock outcrops found in the Glen quadrangle. The Kootenai Formation is broadly associated with terrestrial deposition, while the overlying Blackleaf and Frontier Formations mark a return to marine sedimentation. Beds are generally west dipping with an east dipping foliation, and have been faulted during the Sevier–Laramide orogenies to produce a repetition of Cretaceous strata at the surface.

Igneous intrusive rocks in the area are best represented by the McCartney Mountain pluton. Previous work has assigned a consistent Late Cretaceous crystallization age of ~74 Ma to the pluton. A biotite K/Ar cooling age has been reported as 74 ± 1 Ma (Brumbaugh and Hendrix, 1981), while a weighted mean of five concordant zircons produced a U/Pb crystallization age of 74.5 ± 1.1 (Foster and others, 2012). Smaller, compositionally similar intrusions can be found in the eastern half of the quadrangle. These typically contain hornblende and feldspar phenocrysts identical to those found in the main body of the McCartney Mountain pluton. However, the grain size of the matrix varies considerably, from coarse, to fine, to aphanitic. A lower grain size of the matrix implies that smaller intrusions may have intruded to shallower depths, and/or have cooled faster than the main body of the pluton, allowing less time for formation of a coarse-grained matrix.

Contact metamorphism is largely limited to the immediate periphery of the McCartney Mountain pluton, where it produced skarns in Cretaceous sediments. A minor shear zone is present in the northeast corner of the quadrangle in Cretaceous sediments. Lineations suggest a top to the east motion, possibly associated with syntectonic intrusion of the McCartney Mountain pluton during Sevier–Laramide orogenies. Due to limited exposure in the Glen quadrangle, this shear zone requires additional investigation.

Exposed Tertiary sediments in the Glen quadrangle date from late Eocene to Pliocene time. The stratigraphically lowest exposed unit is the upper Eocene Bone Basin Member of the Renova Formation. Multiple paleontologic investigations have yielded an upper Eocene (Chadronian) fossil assemblage and depositional age of this unit (Riel, 1963; Hoffman, 1971; McHugh, 2003; fig. 3). Overlying fluvial and debris flow deposits of the Cabbage Patch Member of the Renova Formation are coeval with an early phase of Oligocene to early Miocene extension (e.g., Sears and Fritz, 1998). The Renova Formation is overlain by the Sixmile Creek Formation, which includes both proximally sourced debris flow deposits of the Sweetwater Member and distal fluvial deposits of the Big Hole Member. The tuffaceous Anderson Ranch Member of the Sixmile Creek Formation is missing in the Glen quadrangle. Deposition of the Sixmile Creek Formation is coeval with the initiation of rapid Basin and Range style extension beginning in Miocene time (e.g., Sears and Fritz, 1998).

The upper Sixmile Creek Formation is overlain by unconsolidated alluvial fan deposits of the McCartney Mountain Gravels informal map unit. These gravels have been described as either Quaternary or Tertiary during previous mapping efforts (Hoffman, 1971; McDonald and others, 2012; Dolan and others, unpublished). In the adjacent Block Mountain quadrangle to the immediate east, the McCartney Mountain gravels abruptly end at the Timber Canyon Fault, and have no clear source in modern drainage systems, suggesting deposition prior to Quaternary time. The McCartney Mountain gravels have been incised by up to 10 m since deposition, but roughly preserve their conical to fan-shaped depositional morphology.

The youngest deposits in the Glen quadrangle are Quaternary deposits associated with modern or abandoned stream beds and floodplains, colluvium, and modern alluvial fans. The largest area of Quaternary fluvial deposits is associated with the Big Hole River. Additional alluvium was deposited by Birch Creek, and minor drainages.

STRUCTURE

The Glen quadrangle lies within the leading edge of the Sevier–Laramide fold-thrust belt (fig. 1). Folds, thrust faults, and cleavage record crustal thickening and shortening within the fold-thrust belt, broadly synchronous with Late Cretaceous emplacement of the McCartney Mountain pluton in the northeastern corner of the map (Kalakay and others, 2001). Tertiary Basin and Range style extension likely initiated in Miocene time and produced normal faults that crosscut older compressional structures (e.g., Pardee, 1950; Ruppel, 1982).

Paleozoic to Mesozoic strata in the Glen quadrangle likely underwent at least three phases of shortening based on observed orientations of bedding, foliation, and two generations of minor folds. Minor, meter to decameter (feet to tens of feet) scale folds and thrust faults are localized in the Cretaceous Kootenai and Triassic Dinwoody Formations, and are largely absent in the overlying Blackleaf and Frontier Formations (fig. 4). Minor folds are open to close, and generally upright. The earliest phase of deformation (F_1) is likely represented by west-trending minor folds (fig. 5). The first generation of minor folds are overprinted by kilometer scale, north- to northeast-trending folds (F_2). The second phase of deformation produced west- to northwest-dipping beds (fig. 6). Repetition of strata and a north-trending anticline–syncline pair in the southern half of the map area are suggestive of generally east-directed shortening, consistent with thin-skinned deformation associated with the Sevier orogen. A third generation of folds (F_3) are north-trending with an east-dipping foliation, suggestive of a west-verging deformation event (fig. 5). An east-dipping fault in the southern part of the quadrangle may have formed either during this third phase of deformation, or as a backthrust during prior east-verging shortening.

The Cherry Creek syncline is a prominent regional feature that is locally faulted along and across its axis. The fold generally parallels a thrust fault at the western edge of the quadrangle, and may be associated with F_2 folding. The Cherry Creek syncline is likely a footwall syncline contemporaneous with thrusting (Tysdal and others, 1994).

Tertiary extension in the Glen quadrangle likely initiated after late Eocence (Chadronian) time based on the presence of the Bone Gulch Syncline, which deforms the Bone Basin Member of the Renova Formation. In the southeast corner of the quadrangle, gravity modeling by Chandler (1973) implies that Tertiary sediments are up to 762 m (2,500 ft) thick. As Miocene deposits of the Sixmile Creek Formation southeast of the Bone Gulch Syncline are not deformed, I infer that there is a subsurface fault in the area that has not been active since Miocene time. Such a subsurface fault may have been active in Eocene to Oligocene time when it was a locus for deposition of the Renova Formation. Consequentially, the Renova Formation may be significantly thicker in the southeast portion of the quadrangle than it is elsewhere.

Basin and Range style extension in southwestern Montana likely began in Miocene time, and remains active today (e.g., Sears and Fritz, 1998). Normal faulting related to extension produces earthquakes as part of the Intermountain Seismic Belt (Stickney, 2007). The 2005 M_w 5.6 Dillon earthquake occurred 4 km (2 mi) southeast of the quadrangle at a depth of 10.5 km (6.5 mi) (fig. 1). Moment tensor solutions indicated oblique normal faulting with an east–northeast to west–southwest extension direction (Stickney, 2007). Quaternary extension in the Glen quadrangle is accommodated by the Timber Canyon Fault, which contains Tertiary sediments in the hanging wall and Cretaceous sediments and the McCartney Mountain pluton in the footwall. Minor fault scarps observed during geologic mapping indicate that this fault remains active. A Quaternary normal fault may approximate the course of the Big Hole River, promoting incision of Tertiary sediments in the hanging wall of the Timber Canyon Fault. Both faults are consistent with northeast–southwest-directed extension observed in local seismicity. Gravity modeling by Chandler (1973) suggests that motion on these faults produced a local Tertiary basin up to 1,005 m (3,300 ft) deep.

ECONOMIC GEOLOGY

The Glen quadrangle includes portions of the Nogo and McCartney Mountain mining districts. Production in the Nogo district has been minimal due to an overall absence of mineralization, and is wholly absent in the Glen quadrangle. Mining activity in the quadrangle associated with the McCartney Mountain mining district is limited to two prospects, and the Nyhart–Cox mine. Mining focused on lead, gold, and silver mineralization found in skarn associated with contact metamorphism of the Cretaceous Blackleaf Formation by the McCartney Mountain pluton (Montana Department of Environmental Quality Abandoned Mines Historical Narratives, 2018).

Oil exploration in the quadrangle was carried out from 1976 to 1983, and was largely limited to the acquisition of seismic profiles. One wildcat oil well (Hagenbarth 27-22, Montana Board of Oil & Gas Conservation, No. 25001210090000) was drilled in 1980, producing a dry hole. The Hagenbarth 27-22 well is located to the southeast of the I-15 Apex exit, just past the southern boundary of the Glen quadrangle. The well is 12,048 ft deep, and bottoms out in the Flathead Formation. Existing seismic sections were not available during geologic mapping.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated, poorly sorted to well-sorted deposits of gravel, sand, silt, and clay deposited by modern streams and rivers. Cobbles and boulders are generally angular in tributary streams in the western portion of the quadrangle, and well rounded in the Big Hole River in the northeastern portion of the quadrangle. Clasts are predominantly comprised of locally sourced bedrock, including shale, sandstone, limestone, quartzite, and granodiorite. Thickness as much as 12 m (40 ft) based on logs for household groundwater wells.

Qalo **Alluvium, older than Qal (Holocene and Pleistocene?)**—Unconsolidated, poorly sorted to well-sorted deposits of gravel, sand, silt, and clay deposited by streams in Holocene time. Likely represent ancient channels and floodplains of modern streams. Cobbles and boulders generally angular to rounded and consist of locally sourced bedrock, including shale, sandstone, limestone, quartzite, and granodiorite. Thickness as much as 12 m (40 ft).

Qac **Alluvium and colluvium (Holocene and Pleistocene?)**—Unconsolidated poorly sorted deposits of sand, silt, and clay, and gravel, deposited by modern streams and rivers and on adjacent slopes by sheetwash and gravity processes. Variable thickness, generally less than 10 m (33 ft).

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

Qaf **Alluvial fan deposits (Holocene)**—Clay to cobble-sized, angular clasts forming broad conical deposits at outlets of mountain streams. Qaf deposits across the map area likely do not correlate with one another. Up to 10 m (33 ft) thick.

Tmm **McCartney Mountain gravels (Pliocene?)**—Youngest Tertiary sediments exposed on the southern and western flanks of McCartney Mountain. Unconsolidated to loosely consolidated. Gravels are generally tan matrix- and clast-supported granules to boulders with a silt to sand matrix. Clasts are angular sandstone, shale, quartzite, and granodiorite, rarely including subrounded clasts from the underlying Sixmile Creek and Renova Formations. Clast composition changes along the mountain front to reflect local sourcing. Locally contains 5 to 20-cm-thick beds of clast-supported gravels with imbricated angular clasts, interpreted to be braided stream deposits. The cone-shaped morphology of these deposits suggests they formed as alluvial fans, which have been subsequently abandoned and incised. Thickness is at least 10 m (33 ft), and may be significantly greater in the hanging wall of the Timber Canyon Fault.

Tscb **Sixmile Creek Formation, Big Hole Member (Miocene)**—Tan to tan gray, well-sorted, clast-supported, coarse sand to boulder gravel with silty to sandy matrix. Clasts are subrounded to well rounded. Contains tan weathering white, tan, and pink cobbles of Mesoproterozoic Belt Supergroup quartzite and the Cambrian Flathead Formation. Contains subordinate clasts of granite, as well as sandstone and shale sourced from local Mesozoic to Paleozoic strata. Distinguished from other Tertiary sediments based on 1 to10-m-thick beds of tan weathering rounded cobbles comprised of tan and white quartzite. Likely correlates with the Big Hole River Member of the Sixmile Creek Formation as described by Sears and others (2009). Exposures are up to 110 m (360 ft) high. Ranges to more than 120 m (395 ft) thick. Locally missing due to erosion or non-deposition.

Tscs **Sixmile Creek Formation, Sweetwater Creek Member (Miocene)**—Tan to light gray, unlithified to weakly consolidated silt, sand, and gravel with an ashy matrix. Clasts are angular to subangular and are primarily derived from local bedrock. Contains 5 to 60-cm-thick beds of very coarse matrix-supported sand and pebble conglomerate with silty to sandy matrix. Interpreted to be debris flow deposits. Includes 0.1 to 3-m-thick channel deposits of clast-supported, pebble to cobble conglomerate, with subrounded to rounded clasts of predominantly local affinity. Commonly includes 10 to 30-cm-thick massive light gray ashy silt to fine sand beds. Locally contains paleosols with pedogenic carbonate horizon up to 1 m thick. Exposures are up to 50 m (164 ft) high. At least 60 m (200 ft) thick based on domestic groundwater well logs in the Glen quadrangle. May correlate with the Sweetwater Creek Member of the Sixmile Creek Formation as described by Sears and others (2009). Locally missing due to erosion or non-deposition.

Trcp **Renova Formation, Cabbage Patch Member (Oligocene–Early Miocene)**—Gray, gray tan, and white, well-sorted, clast-supported pebble to cobble conglomerate with fine to coarse sand matrix. Clasts are subrounded to rounded. Contains white, tan, pink, and purple quartzite, sandstone, and granite. Interbedded with poorly sorted, matrix-supported conglomerate, with a medium to coarse litharenite matrix and rare angular to subangular pebbles to large boulders of granite, and quartzite. Distinguished from Tsc based on lithification (i.e., Tsc is unlithified, Trcp is lithified), presence of both matrix and clast-supported beds, and abundant pink and purple quartzites likely sourced from Mesoproterozoic Belt Supergroup strata. May correlate with the Cabbage Patch Member of the Renova Formation. Thickness is at least 10 m (33 ft) based on exposures southwest of McCartney Mountain and logs for nearby domestic groundwater wells, but may be significantly thicker in the hanging wall of the Timber Canyon Fault. Unconformably overlies Trbb in the adjacent Block Mountain quadrangle. Locally missing due to erosion or non-deposition.

Trbb **Renova Formation, Bone Basin Member (Late Eocene)**—Tan gray to white siltstone and tuffaceous siltstone. Massive with no discernible bedding, and rare matrix-supported granules of quartz and lithic grains. Locally contains 1 to 5-m-wide channels of fine- to very coarse-grained micaceous sandstone dominated by quartz and feldspar, with minor lithic grains. Fossil assemblages collected in the Glen quadrangle and the adjacent Block Mountain quadrangle indicate a Late Eocene (Chadronian) depositional age (Riel, 1963; Hoffman, 1971; McHugh, 2003; fig. 3). At least 200 m (656 ft) thick (McHugh, 2003), but may be significantly thicker, as gravity modeling by Chandler (1973) suggests that Tertiary sediments south of the Timber Canyon Fault may be up to 1,005 m (3,300 ft) thick.

Kgd **Granodiorite to Porphyritic Dacite (Late Cretaceous)**—Gray, porphyritic, coarse-grained biotite granodiorite with common feldspar and hornblende. Smaller granodiorite to porphyritic dacite intrusions south of the Big Hole River have feldspar and hornblende phenocrysts in a medium-grained to aphanitic matrix. Jointing is common with a 0.5–2 m spacing, with coarser-grained portions of the intrusion having greater joint spacing. The McCartney Mountain pluton has yielded a biotite K/Ar cooling age of 74 ± 1 Ma (Brumbaugh and Hendrix, 1981) and a U/Pb crystallization age of 74.5 ± 1.1 based on a weighted mean of five concordant zircons (Foster and others, 2012).

Kf **Frontier Formation (Late Cretaceous)**—Dominantly gray, brownish gray, and greenish gray siltstone and mudstone, and subordinate medium- to coarse-grained, and locally very coarse-grained sandstone, conglomerate, and minor porcellanite. The beds of mudstone, siltstone, limestone, and sandstone form fining-upward depositional cycles tens of meters thick. Sandstone and conglomerate are rich in quartz and chert. Sandstones typically have distinctive low amplitude (~10–20 cm) and high wavelength (1–2 m) 3D ripples, which are not present in the underlying Blackleaf Formation. Conglomerate clasts are rounded pebbles and small cobbles. Lower 100–200 m (330–660 ft) is distinctive brown to brownish gray siltstone and mudstone. Top not exposed but thickness about 900 m (3,000 ft) north of the quadrangle (Tysdal and others, 1994; Dyman and Nichols, 1988).

Kbl **Blackleaf Formation, undivided (Early to Late Cretaceous)**—Dark gray, yellow, maroon, gray green, and yellowish gray siltstone, mudstone, and porcellanite. Interbedded with gray to yellow fine- to medium-grained sandstone with common quartz and chert grains. Distinguished from the overlying Frontier Formation based on dominance of siltstones and mudstones over sandstones, presence of porcellanite, and absence of large 3D ripples in sandstone units. The contact between the Blackleaf and Frontier Formations is placed at the top of a porcellanite bed that directly overlies the stratigraphically highest maroon mudstone (Tysdal and others, 1994; Dyman and Tysdal, 1998). Near the McCartney Mountain pluton, and smaller granodiorite intrusions, the Blackleaf Formation has undergone contact metamorphism, which makes it difficult to distinguish between the Vaughn and Flood Members. Total thickness approximately 700 m (2,300 ft).

Where possible, the Blackleaf Formation is divided into two members:

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

Kbf **Blackleaf Formation, Flood Member (Early Cretaceous)**—Pale brown to brownish gray, green, red, and gray, fine- to medium-grained and locally coarse-grained to conglomeratic, quartz- and chert-rich lithic sandstone, shale, calcareous siltstone, siltstone, and conglomerate. Trough crossbedding common in sandstone (Tysdal and others, 1994; Dyman and Nichols, 1988). Thickness about 213 m (700 ft).

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

Trd **Dinwoody Formation (Early Triassic)**—Interbedded shale, limestone, and calcareous sandstone characterized by platy, thinly laminated beds that weather a distinctive pale to light grayish brown. Upper part has massive calcareous, rippled sandstone beds as much as 1 m (3 ft) thick with shaley interbeds and massive, gray, pinkish gray weathering, limestone as much as 1 m (3 ft) thick. Phosphatic pelecypod *Lingula* and fish bone fossils are locally abundant. Lower part is predominantly olive drab, chippy-weathering, hard fissile shale with interbedded dark brown weathering, silty limestone beds 10 cm (4 in) or thinner. Thickness about 260–275 m (650 ft) (Myers, 1952).

Psp **Shedhorn and Phosphoria Formations, undivided (Permian)**—Shedhorn Formation is grayish brown, fine-grained, thin- to thick-bedded quartz sandstone and cherty sandstone with chert and quartz cement. Vertical and horizontal burrows are common. Phosphoria Formation is dark gray to black, carbonaceous and phosphatic mudstone with scarce phosphate beds, grayish and gray brown cherty quartz sandstone, cherty or sandy dolomite, fine-grained dolomitic sandstone, and yellowish tan sandy siltstone with subordinate beds of vitreous quartz sandstone. Poorly exposed, typically covered by colluvium and talus of underlying Quadrant Formation. Thickness approximately 110 m (360 ft) in Twin Adams quadrangle to the immediate west (Sharp, 1970).

Pq **Quadrant Formation (Pennsylvanian)**—White to light yellowish brown, fine-grained, vitreous, quartz sandstone. Beds are mostly thick to massive, locally with faint cross-laminations. Near fault zones forms a tan to red quartzite cemented breccia with angular pebble- to cobble-sized clasts of white to tan quartzite. Thickness approximately 283 m (930 ft) in the Twin Adams quadrangle to the immediate west (Sharp, 1970).

Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey under Contract Number G18AC00200.
GIS production: Yiwen Li and Paul Thale, MBMG. Map layout: Susan Smith, MBMG. Editing: Susan Barth, MBMG.

REFERENCES

Brumbaugh, D.S. and Hendrix, T.E. 1981. The McCartney Mountain structural salient, southwestern Montana: Montana Geological Society Field Conference and Symposium Guidebook to SW Montana, p. 201–209.
Chandler, V.W., 1973, A gravity and magnetic investigation of the McCarthy Mountain area, Beaverhead and Madison Counties, Montana: Missoula, University of Montana, M.S. thesis, 47 p., 1 sheet, scale 1:24,000.
Dolan, M., McCarthy, Y., and Hendrix, M.S., unpublished, Geologic map of southern McCartney Mountain, southwest Montana, 1 sheet, scale 1:24,000.
Dyman, T.S., and Nichols, D.J., 1988, Stratigraphy of mid-Cretaceous Blackleaf and lower part of the Frontier Formations in parts of Beaverhead and Madison Counties, Montana: U.S. Geological Survey Bulletin 1773, 31 p.
Dyman, T.S., and Tysdal, R.G., 1998, Stratigraphy and depositional environment of nonmarine facies of Frontier Formation, eastern Pioneer Mountains, southwestern Montana: The Mountain Geologist, v. 35, no. 3, p. 115–125.
Foster, D.A., Mueller, P.A., Heatherington, A., Gifford, J.N., and Kalakay, T.J., 2012, Lu–Hf systematics of magmatic zircons reveal a Proterozoic crustal boundary under the Cretaceous Pioneer batholith, Montana: Lithos, v. 142–143, p. 216–225, doi: https://doi.org/10.1016/j.lithos.2012.03.005.
Gibson, R.I., 2007, Mesozoic sedimentation in southwest Montana: Northwest Geology, v. 36, p. 57–66.
Hoffman, D.S., 1971, Tertiary vertebrate paleontology and paleoecology of a portion of the Lower Beaverhead River Basin, Madison and Beaverhead Counties, Montana: Missoula, University of Montana, Ph.D. dissertation, 168 p., 1 sheet, scale 1:48,000.
Kalakay, T.J., John, B.E., and Lageson, D.R., 2001, Fault-controlled pluton emplacement in the Sevier fold-and-thrust belt, SW Montana: Journal of Structural Geology, v. 23, p. 1151–1165.
McDonald, C., Elliott, C.G., Vuke, S.M., Lonn, J.D., and Berg, R.B., 2012, Geologic map of the Butte South 30' x 60' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 622, 1 sheet, scale 1:100,000.
McHugh, J.B., 2003, Microfaunal succession and stratigraphy of the Bone Basin Member (Renova Formation) at McCarty's Mountain and Mantle Ranch, southwest Montana: Pocatello, Idaho State University, M.S. thesis, 142 p.
Montana Department of Environmental Quality, Abandoned Mines Historical Narratives, http://deq.mt.gov/Land/AbandonedMines/linkdocs/ [accessed 10/09/2018].
Myers, W.B., 1952, Geology and mineral deposits of the northwest quarter Willis quadrangle and adjacent Brown's Lake area, Beaverhead County, Montana: U.S. Geological Survey Open-File Report 52-105, 46 p., 1 sheet, scale 1:31,680.
Pardee, J.T., 1950, Late Cenozoic block faulting in western Montana: Geological Society of America Bulletin, v. 61, no. 4, p. 359.
Riel, S.J., 1963, A basal Oligocene local fauna from McCarty's Mountain, Southwest Montana: Missoula, University of Montana, M.S. thesis, 74 p., 2 plates, scale 1:2,852 and 1:9,250.
Ruppel, E.T., 1982, Cenozoic block uplifts in east-central Idaho and southwest Montana: U.S. Geological Survey Professional Paper, v. 1224, 24 p.
Ruppel, E.T., O'Neill, J.M., and Lopez, D.A., 1993, Geologic map of the Dillon 1º x 2º quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1803-H, scale 1:250,000.
Scarberry, K.C., Elliott, C.G., Yakovlev, P.V., 2019, Geologic map of the Butte North 30' x 60' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open-File Report 715, 30 p., 1 sheet, scale 1:100,000.
Sears, J.W., and Fritz, W.J., 1998, Cenozoic tilt domains in southwestern Montana: Interference among three generations of extensional fault systems, *in* Special Paper 323: Accommodation zones and transfer zones; the regional segmentation of the Basin and Range Province: Geological Society of America, p. 241–247.
Sears, J.W., Hendrix, M.S., Thomas, R.C., and Fritz, W.J., 2009, Stratigraphic record of the Yellowstone hotspot track, Neogene Sixmile Creek Formation grabens, southwest Montana: Journal of Volcanology and Geothermal Research, v. 188, no. 1–3, p. 250–259.
Sharp, G.C., 1970, Stratigraphy and structure of the Greenstone Mountain area, Beaverhead County, Montana: Corvallis, University of Oregon, M.S. thesis, 121 p., 1 plate, scale 1:24,000.
Stickney, M., 2007, Historic earthquakes and seismicity in southwestern Montana: Northwest Geology, v. 37, p. 167–186.
Tysdal, R.G., Dyman, T.S., and Lewis, S.E., 1994, Geologic map of Cretaceous strata between Birch Creek and Brownes Creek, eastern flank of Pioneer Mountains, Beaverhead County, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-2434, scale 1:24,000.
Zartman, R.E., Dyman, T.S., Tysdal, R.G., and Pearson, R.C., 1995, U-Pb ages of volcanogenic zircon from porcellanite beds in the Vaughn Member of the mid-Cretaceous Blackleaf Formation, southwestern Montana, *in* Shorter contributions to the stratigraphy and geochronology of the Upper Cretaceous rocks in the Western Interior of the United States: U.S. Geological Survey Bulletin 2113-B, p. B1–B15.

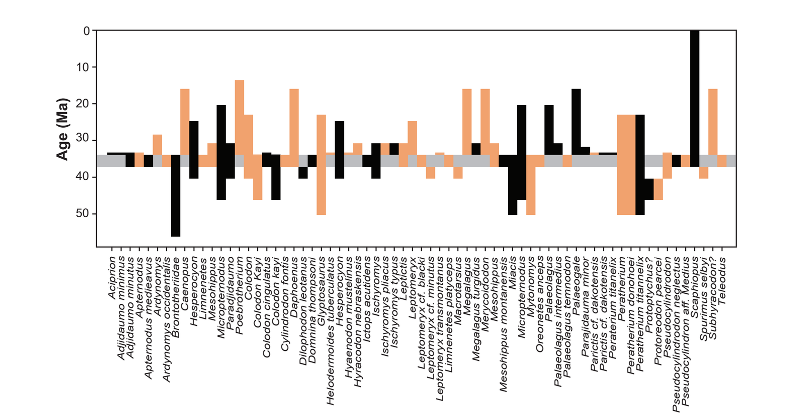


Figure 3. Fossil assemblage for the Bone Basin Member of the Renova Formation in the Dillon 30' x 60' quadrangle (Riel, 1961; Hoffman, 1971; McHugh, 2003). Bars show age range of each taxon found in the Dillon quadrangle. Taxa located at the Bone Gulch locality (this quadrangle, labeled on map) shown in orange. Gray bar shows the inferred Chadronian deposition age based on the most recent extinctions, and most recent first appearances of all taxa.

Figure 4. Minor meter scale folds (F_1) in the Cretaceous Kootenai Formation. Looking north toward McCartney Mountain.

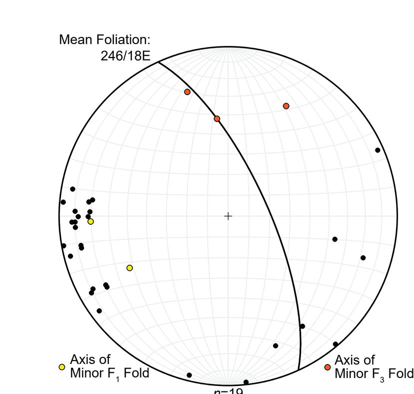


Figure 5. Lower hemisphere projection of poles to foliation measured from Mesozoic to Paleozoic strata. Data are plotted on an equal-area stereonet.

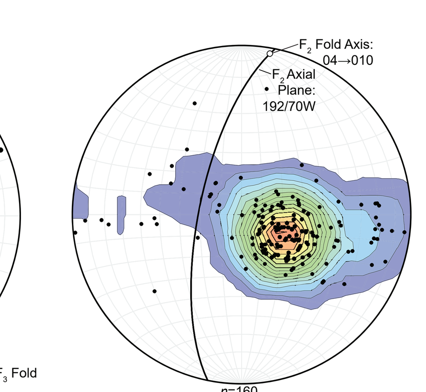


Figure 6. Lower hemisphere projection of poles to bedding measured from Mesozoic to Paleozoic strata. Data are plotted on an equal-area stereonet, and are shown with 2σ Kamb contours.

MBMG Geologic Map 74

Geologic Map of the Glen 7.5' Quadrangle, Southwestern Montana

Petr Yakovlev

2019