GEOLOGIC MAP OF THE CANYON FERRY LAKE AREA WEST-CENTRAL MONTANA

Compiled* and mapped by
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*Bedrock largely compiled from previous mapping except in the Spokane Hills area.

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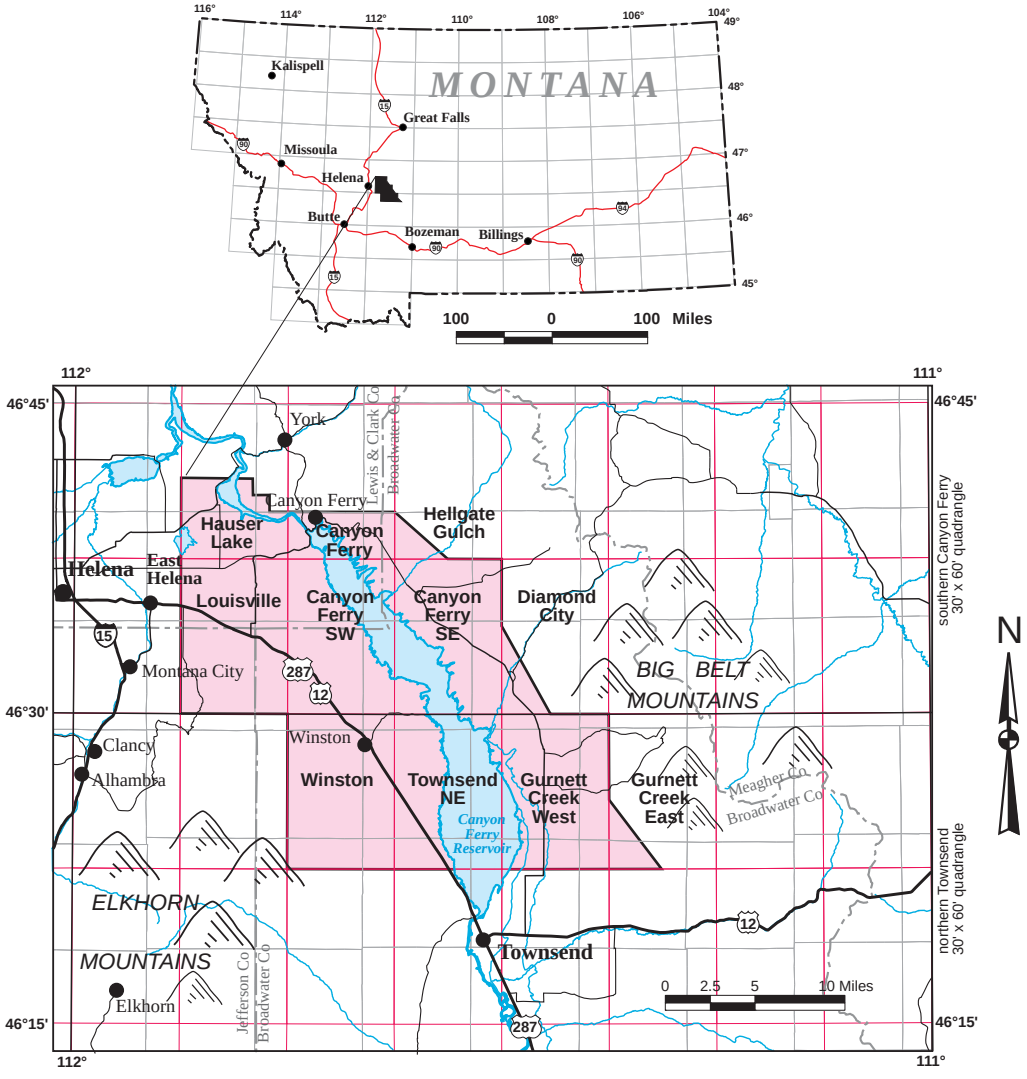
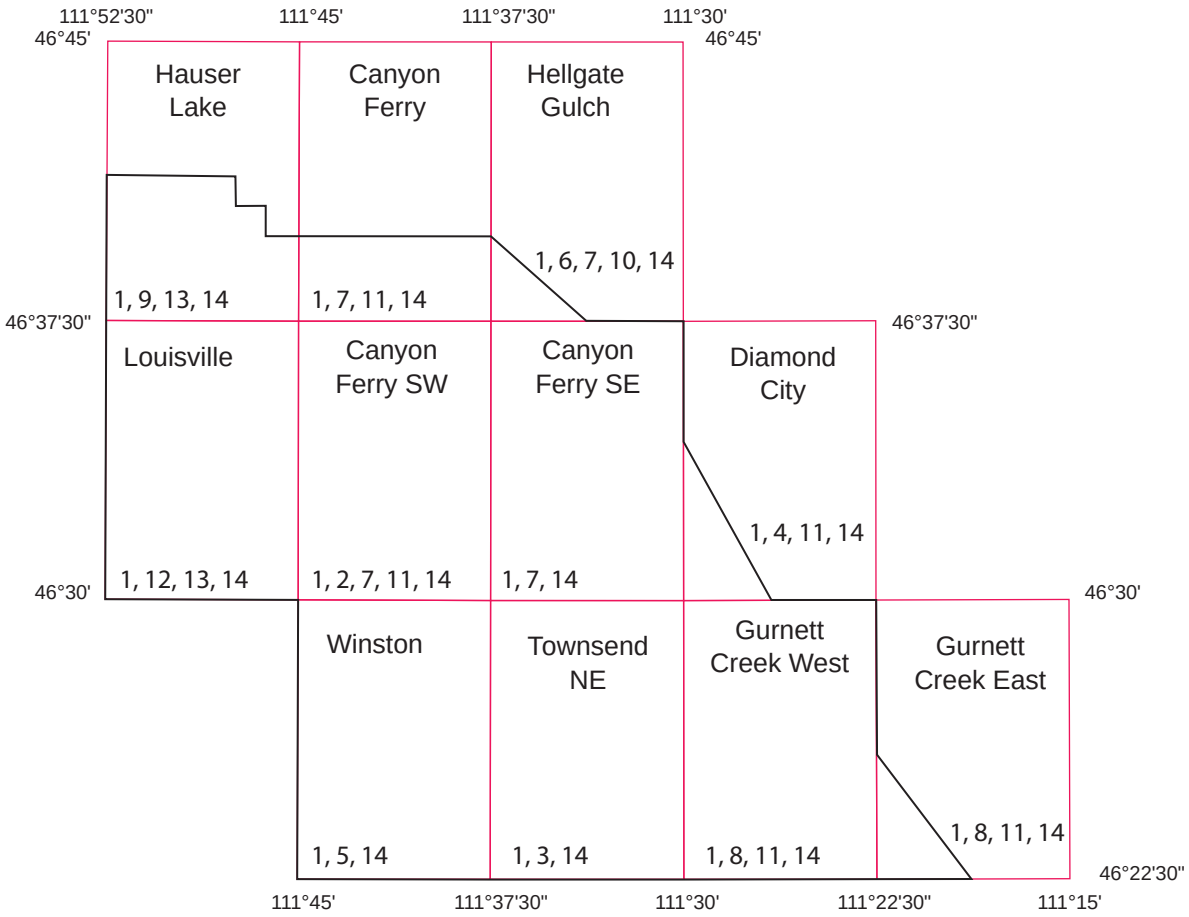


Figure 1. Location of map area.



1. Anderson and LaForge, 2003, figure 3.
2. Becraft, 1958, plate 4, scale 1:24,000.
3. Freeman, Ruppel, and Klepper, 1958, plate N, scale 1:48,000.
4. Gualtieri, 1975, scale 1:48,000.
5. Klepper, Ruppel, Freeman, and Weeks, 1971, plate 1, scale 1:48,000.
6. Lonn and McDonald, 2003, scale 1:24,000.
7. Mertie, Fisher, and Hobbs, 1951, plate 1, scale 1:48,000.
8. Nelson, 1963, plate 1, scale 1:62,500.
9. Pardee and Schrader, 1933, plate 15, scale 1:63,360.
10. Reynolds and Brandt, 2006, scale 1:100,000.
11. Reynolds and Brandt, 2005, scale 1:100,000.
12. Smedes, 1966, plate 1, scale 1:48,000.
13. Stickney, 1987, scale 1:50,000.
14. Stickney and others, 2000, scale 1:100,000.

Figure 2. Sources of Geologic Mapping

Description of Map Units
Geologic Map of Canyon Ferry Lake area

Qal **Alluvium** (Holocene)—Unconsolidated gravel, sand, silt, and clay in modern stream valleys. Clasts generally cobble size and smaller, but boulders abundant in some mountain stream valleys.

Qac **Alluvium and colluvium, undivided** (Holocene)—Argillaceous silt and sand with lenses of coarser sediment, generally pebble size or smaller.

Qls **Landslide deposit** (Holocene)—Mass-wasted deposit that consists of stable to unstable, unsorted mixtures of clay- to boulder-size sediment. Includes rotated or slumped blocks of bedrock and surficial sediment, earthflow deposits, and mudflow deposits. Color and lithology reflect that of transported parent rock and surficial materials. *Northern Elkhorn Mountains* (Stickney, 1987)—Unsorted, unstratified mixture of soil and angular volcanic boulders as much as 1.5 m (5 ft) in diameter.

Qpa **Paludal deposit** (Holocene)—Argillaceous silt, sand, and organic matter deposited in swamp and pond environments.

Qe **Eolian deposit** (Holocene)—Light brown to light gray, unconsolidated, stratified wind-blown sand and silt. Thickness generally less than 6 m (20 ft).

Qec **Eolian and colluvial deposits** (Pleistocene)—*Northern Spokane Hills* (Pardee and Schrader, 1933; Stickney, 1987)—Locally derived, fine-grained gravel and loess composed of unstratified, well-sorted, tan to light brown, wind-blown silt with minor very fine grained sand and clay. Thickness 1.5-10 m (5 to 30 ft).

Qgr **Gravel** (Pleistocene)—*Elkhorn Mountains* (Smedes, 1966; Stickney, 1987)—Gravel of various sources that includes alluvial fans, mudflows, lag from underlying Tertiary deposits, and old landslide deposits. Weakly stratified, poorly sorted, pebble to boulder gravel in a grayish brown to yellowish light gray clay, silt, and sand matrix. Clasts are well rounded to subrounded and range to as much as 2 m (6 ½ ft) in diameter with a median size of 2-5 cm (1-2 in).

Qta **Talus deposit** (Holocene)—*Spokane Hills* (Stickney, 1987)—Unconsolidated, unsorted angular boulders and cobbles of resistant bedrock (mainly Flathead Formation quartzite) on and below steep slopes.

Qaf **Alluvial-fan deposit** (Holocene)—Unconsolidated gravel, sand, silt, and clay in deposits with fan-shaped morphology at break in slope. Some alluvial-fan deposits dominantly fine-grained, others dominantly coarse-grained. Moderately well sorted in channels to poorly sorted and matrix-supported in debris-flow component.

The following Qaf units (Holocene and Pleistocene) refer to a system of alluvial fans in the Winston area.

Qaf5 **Alluvial-fan deposit, youngest** (Holocene)—Relatively unweathered cobbles and boulders of volcanic rocks and dioritic intrusive rocks, mostly subrounded or rounded.

Qaf4 **Alluvial-fan deposit** (Holocene)—Younger than Qaf3, older than Qaf5.

Qaf3 **Alluvial-fan deposit** (Holocene and Pleistocene?)—Younger than Qaf2, older than Qaf4.

Qaf2 **Alluvial-fan deposit, second oldest** (Pleistocene)—Younger than Qaf1, older than Qaf3. Large glacial outwash fan at mouth of Beaver Creek near Winston consists of subrounded to subangular resistant fragments of volcanic and intrusive rocks as much as 5 dm (18 inches) in diameter in a closely packed heterogeneous matrix. (Klepper and others, 1971).

Qaf1 **Alluvial-fan deposit, oldest** (Pleistocene)—Deeply weathered fan deposit; only the most resistant volcanic rocks preserved.

Qbaf **Alluvial-fan deposit with abundant boulders** (Pleistocene)—Eroded alluvial fan deposit mapped as the extent of lag boulders and associated finer grained deposits. Fan morphology no longer apparent. Boulders dominantly quartz monzonite from the Boulder Baldy pluton to the east of the map area.

Qalb **Alluvium with abundant boulders** (Holocene and Pleistocene)—Unconsolidated gravel, sand, silt, and clay in modern stream valleys. Abundant boulders in gravel fraction.

Qat **Alluvial terrace deposit** (Holocene and Pleistocene)—*Hauser Lake area* (Stickney, 1987; Pardee and Schrader, 1933. Unconsolidated to cemented alluvial terrace deposits along the Missouri River and Hauser Lake composed of light gray to brown, weakly bedded, moderately well sorted and well rounded, silty and sandy pebble and cobble gravel at various elevations to as much as 75 m (250 ft) above the Missouri River and Hauser Lake. Uppermost level (oldest deposit) caliche-cemented. Deposits along the Missouri River have yielded gold and sapphires. Composite thickness of multiple terrace deposits as much as 24 m (80 ft).

Qbac **Alluvium and colluvium with abundant boulders**—Unconsolidated deposit at the southern end of the Spokane Hills with abundant large clasts of quartz monzonite and quartzite as much as 5 m (16 ft) in diameter.

Qc **Colluvium** (Holocene)—Unconsolidated angular to subrounded clasts, boulder size and smaller, derived from adjacent rock dominantly by sheetwash and creep.

Qdf **Debris-flow deposit** (Pleistocene)
Northern part of map area. Angular and rounded locally derived boulders and cobbles of Paleozoic limestone and quartzite, and locally derived Proterozoic rocks, floating in a

fine-grained, light-colored matrix; or clast-supported boulders and cobbles in lenses. Matrix includes abundant flat clasts of Belt Supergroup rocks. Pleistocene gastropods on north side of Chinaman Cove (K. Constenius, written communication, 2010). *Southeastern part of map area*. Angular and rounded boulders and cobbles floating in fine-grained matrix. Coarse clasts almost exclusively granodiorite in some deposits. Coarse clasts of other deposits are Paleozoic limestone and quartzite and local Proterozoic rocks.

Qm **Mantle deposit** (Pleistocene)
Western part of map area. Angular boulders and cobbles composed of Elkhorn Mountains Volcanics with subordinate quartzite in lag deposits, probably from older alluvial fans from the Elkhorn Mountains. Many large boulders, some as large as 1.5 m (5 ft) in diameter, some in boulder fields. Thickness variable according to size of clasts, as thick as 25 m (80 ft).
Southeastern map area. Deposits include regolith and lag deposits as large as boulder size derived from underlying Tertiary deposits and from Pleistocene debris-flow deposits, subordinate water-transported deposits and colluvium. Unit includes eolian deposits that overlie coarser deposits. Thickness generally less than 6 m (19 ft), including eolian deposits, but as much as 12 m (40 ft).

Qp **Pediment deposit** (Pleistocene)—Veneer of unconsolidated locally derived clasts that range from boulder size near source to sand, silt, and clay. Subangular to subrounded clasts from locally derived sources. Thickness equivalent to largest clast size in immediate area.

Qpe **Pediment and eolian deposits** (Pleistocene)—*West side of Spokane Hills* (Stickney, 1987). Loess composed of unstratified, well-sorted, tan to light brown, wind-blown silt with minor very fine sand and clay. Thickness as much as 10 m (32 ft). Loess overlies gravel composed of brown, tan, and gray, poorly sorted, unstratified, sandy and silty locally derived, subrounded and subangular clasts. Veneer of unconsolidated, locally derived pediment deposit on surface. Thickness averages 1-2 m (3-6 ft).

Qwi **Winston map unit** (Pleistocene)—Pinkish gray and orangish brown silt and fine-grained sand, silt, and clay that alternate with coarser clasts including rounded and subrounded duriclast cobbles and subordinate pebbles and small boulders. In some areas fine-grained sediment is sharply cut by channels of the coarser fraction. Coarse clast composition quartz, quartzite, and granitic rock in a sandy matrix. Local wavy bedding in fine fraction. Poorly indurated fossils. Paired ash beds, white above and gray below, exposed in lake-margin cliffs. Exposed thickness 25 m (80 ft).

Qgt **Glacial till** (Pleistocene)—Unconsolidated, poorly sorted sand, pebbles, cobbles and boulders, some of which are striated, in small valley moraine deposits. Thickness 20 m (60 ft).

Qgl **Glacial lake deposit** (Pleistocene: Illinoian and Wisconsin)—*Hauser Lake area* (Stickney, 1987; Reynolds and Brandt, 2005). Brown, grayish dark brown, light yellowish gray, very light gray , and very pale grayish orange, thinly bedded and locally laminated, silt, fine-

grained sand, and clay. Deposits 50-75 m (165-245 ft) above Hauser Lake include a 1 m-(3 ft-) thick caliche layer. Thickness of deposit as much as 18 m (60 ft).

QTls **Landslide deposit** (Pleistocene and/or Pliocene?)—*Northern Elkhorn Mountains* (Smedes, 1966). Weathered boulder deposit. Thickness about 90 m (300 ft).

QTs **Sediment, undivided** (Pleistocene and/or Tertiary)—Deposits along northwest shore of Canyon Ferry Lake that rest on quartz monzonite (Kqm). Grayish orange and yellowish gray, fine-grained tuffaceous silt and fine-grained sand with floating coarse sand grains and small granules. Rubble zone at contact with underlying intrusive rock. Good exposure near Lorelei Picnic area on northwest side of Canyon Ferry Lake. May be same unit as Ts. Deposits patchy and generally less than 6 m (20 ft) thick.

Tgr **Gravel** (Tertiary)—Unconsolidated to locally cemented, gravel deposit with larger clasts dominantly subangular to subrounded resistant cobbles and pebbles with subordinate small boulders; matrix of sand, silt, and clay. Cemented near Clasoil. Thickness 80 m (260 ft).

Ts **Sediment, undivided** (Tertiary)—Grayish orange to yellowish gray, and locally reddish gray fine-grained argillaceous sand and silt, locally cemented, with floating larger sand and granule grains. Massive with small flat clasts derived from local Proterozoic rocks. Powdery when dry. Overlies Climbing Arrow Formation south of Hauser Lake, but age is not known. Thickness 50 m (160 ft).

Tscu **Sixmile Creek Formation, upper** (Tertiary: Miocene and Pliocene?)—Pinkish tan to locally reddish brown silty deposit that may have either lenses or homogeneously distributed larger clasts that are typically angular flat clasts derived from the Belt Supergroup, including Greyson, Newland, Spokane, Helena, and Empire Formations. Exposed thickness about 180 m (600 ft).

Tsct **Sixmile Creek Formation, Toston member** (Tertiary: Miocene)—Gray and light gray, fluvial, cross-bedded gravel/conglomerate of dominantly rounded and subrounded cobbles and pebbles of Belt Supergroup quartzite, mafic volcanic and granitic intrusive rock, and well-cemented sandstone with sandy, tuffaceous matrix. Both clast-supported and matrix-supported with subordinate boulders and pebbles. Prominent white ash bed in many locations or rip-up clasts composed of white ash bed. Other rip-up clasts of pinkish siltstone. Locally crossbed sets are as much as 3 m (10 ft) high. Pebbly sand/sandstone in some places, especially to north. Fossils that could be as old as Hemingfordian but are likely Barstovian (A. Tabrum, written communication, 2010) have been found in this unit in the map area. Thickness 30-75 m (100-250 ft).

Tscl **Sixmile Creek Formation (lower)** of Robinson (1967) (Tertiary: Arikareean)—Alternating coarse- and fine-grained beds and lenses that range from 1 dm (4 inches) to 20 m (65 ft) thick. Coarse beds and lenses are matrix-supported or clast-supported and poorly size-sorted with clasts as large as boulders. Dominantly flat clasts of siltite, and blocky clasts of limestone. Fine-grained beds are grayish orange, argillaceous siltstone and fine-grained sandstone, and grayish brown coarser-grained sandstone. About 60 m (200 ft) exposed in map area.

Twe **White Earth map unit** (Tertiary: Oligocene and Miocene?)—A variety of lithologies that include grayish orange, silty mudstone, locally with breccia lenses and tuff and tuffaceous mudstone; gray, fine-grained sandstone that may be porous or tightly cemented; many orangish brown, irregular silicified beds; brown and black paper shale with local exceptionally preserved insects and plants (CoBabe and others, 2002); subordinate light gray marl beds, and calcareous paleosols with abundant plant material. Arikareean fossils have been identified from the map unit (CoBabe and others, 2002). About 50 m (160 ft) exposed in map area.

Tdc **Dunbar Creek Formation** (Tertiary: Oligocene and Eocene)—Grayish orange, yellowish gray, tuffaceous siltstone and subordinate yellowish gray, calcareous, fine-grained sandstone, and occasional very light gray tuff with floating sand-size glassy grains. Includes closely to widely spaced lenses of coarser, angular to subangular clasts that range to boulder size and are primarily derived from local Belt Supergroup rocks and secondarily from local Paleozoic limestone. Lenses are the color of the coarse clasts. Formation contains large nodular concretions in the Court Sheriff area. Chadronian and Orellan fossils have been identified from the Canyon Ferry, Court Sheriff, and Cemetery Island areas at the north end of Canyon Ferry Lake (White, 1954). Thickness 45-60 m (150-200 ft).

Tca **Climbing Arrow Formation** (Tertiary: Eocene)
Upper: White, light gray, gray, yellowish gray, and yellowish brown altered tuff and lapilli tuff; gray, brown, and olive brown bentonitic mudstone; and tuffaceous sandstone, conglomerate, and breccia with many brown or black thin beds of carbonaceous shale, locally with plant impressions, and chert.
Lower: Red, greenish gray, and brown tuffaceous or bentonitic mudstone and brown or gray granule-pebble conglomerate and sediment, and greenish gray sandstone or sand. Chadronian fossils have been identified from north of Beaver Creek along the lake shore (White, 1954). Thickness of formation approximately 600 m (2000 ft).

Tql **Quartz latite** (Eocene)—*Elkhorn Mountains* (Smedes, 1966). Light gray quartz latite porphyry with abundant large phenocrysts of plagioclase and quartz, sparse phenocrysts of K-feldspar and small flakes of biotite, and slender prisms of hornblende, in a microcrystalline base largely of quartz and K-feldspar.

TKmi **Mafic intrusive rock** (Eocene or Late Cretaceous)—Dark gray to black intrusive rock of undetermined mafic composition.

Ki **Intrusive rock, undivided** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Seriate syenodiorite porphyry that grades either into granodiorite porphyry or diorite porphyry.

Kia **Intrusive rock with augite phenocrysts** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Seriate syenodiorite porphyry that grades either into granodiorite porphyry or diorite porphyry and contains augite phenocrysts.

Kih **Intrusive rock with hornblende phenocrysts** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Seriate syenodiorite porphyry that grades either into granodiorite porphyry or toward diorite porphyry with hornblende phenocrysts.

Kio **Intrusive rock with olivine phenocrysts** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Seriate syenodiorite porphyry that grades either into granodiorite porphyry or toward diorite porphyry with olivine phenocrysts.

Kemma **Elkhorn Mountains Volcanics**, **middle unit welded tuff** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Thick unit of rhyolitic welded tuff.

Kemmt **Elkhorn Mountains Volcanics**, **middle unit tuff** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Thick unit of andesitic and rhyodacitic tuff.

Kemmu **Elkhorn Mountains Volcanics, middle unit, undivided** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Sheets of rhyolitic welded tuff from ash flows that alternate with andesitic and rhyodacitic tuff and tuff breccia. Thickness about 915 m (3,000 ft).

Kemla **Elkhorn Mountains Volcanics, lower unit welded tuff** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Thick unit of quartz latitic welded tuff.

Kemlt **Elkhorn Mountains Volcanics, lower unit tuff** (Late Cretaceous)—*Elkhorn Mountains*. Thick unit of quartz latitic tuff.

Kemlu **Elkhorn Mountains Volcanics, lower unit, undivided** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Rhyodacitic, trachyandesitic, and basaltic pyroclastic and epiclastic volcanic rocks, autobrecciated lavas, and related ash flows.

Kmz **Monzonitic lamprophyre** (Late Cretaceous)—*Spokane Hills* (Mertie and others, 1951). Dark intrusive of medium granularity genetically related to quartz monzonite to east but with more mafic minerals (primarily hornblende and biotite) and less quartz.

Kmzd **Monzodiorite** (Late Cretaceous)—*Elkhorn Mountains* (Reynolds and Brandt, 2005). Very light olive gray, very light gray, and yellowish gray medium crystalline and porphyritic quartz monzodiorite. Phenocrysts of perthitic alkali feldspar in matrix of intercrystalline quartz, plagioclase feldspar, hornblende, and rare biotite.

Kqm **Quartz monzonite** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Butte Quartz Monzonite of Boulder Batholith contains large phenocrysts of plagioclase, K-feldspar, and quartz in a fine-grained sucrosic groundmass. Phenocrysts and groundmass each make up about half the rock. Map unit includes subordinate granodiorite.
Note that following the current IUGS modal classification system (LeBas and Streckeisen, 1991), the Butte pluton of the Boulder Batholith is compositionally a monzogranite.

Spokane Hills (Mertie and others, 1951). Gray, coarsely crystalline granitic rock mottled by light-colored crystals of quartz and feldspar and dark-colored crystals of biotite and

other mafic minerals. Some is porphyritic with tabular crystals of feldspar. To the south, grades to darker more mafic nonporphyritic rocks of medium granularity.

Big Belt Mountains—Boulder Baldy pluton (Reynolds and Brandt, 2005): Light gray to yellowish gray and pinkish gray, finely to medium crystalline phenocrysts. Groundmass of alkali feldspar and rare quartz with phenocrysts of alkali feldspar, biotite, hornblende, and aegirine augite; outer part of pluton has common fluorite as an accessory mineral.

Kla **Latite** (Late Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971). Biotite-hornblende latite porphyry with phenocrysts of plagioclase, biotite, hornblende, and subordinate quartz in a very fine grained indeterminate groundmass.

Big Belt Mountains (Mertie and others, 1951). Light to medium gray porphyritic rocks with phenocrysts of plagioclase in a fine-grained groundmass.

Kset **Slim Sam, Eagle, and Telegraph Creek Formations, undivided** (Slim Sam Formation of Klepper and others, 1971; revised to these three formations by Tysdal, 2000) (Late Cretaceous)—*Elkhorn Mountains* (Tysdal, 2000). Slim Sam Formation Medium gray to grayish green volcanic and volcaniclastic rock with a few beds of pyroclastic tuff, but mainly volcanic debris reworked by sedimentary processes. Eagle Formation Feldspar-chert-quartz sandstone overlain by silty sandstone and medium-grained magnetite-bearing sandstone that also contains hornblende, chert, quartz, and feldspar. The latter intertongues with, and is overlain by, planar-bedded fine-grained sandstone devoid of trace fossils. Upward, this sandstone contains lenses of mudstone that display traces of plant rootlets. Telegraph Creek Formation Interbedded dark gray mudstone and shale and clayey and silty fine-grained sandstone. The sandstone content increases upward. Trace fossils common on and within sandstone beds. Thickness of three formations undivided, 200-350 m (650-1,150 ft) (Tysdal, 2000).

Ket **Eagle and Telegraph Creek Formations**, undivided (Late Cretaceous)—*Elkhorn Mountains* (Tysdal, 2000). Eagle Formation Feldspar-chert-quartz sandstone overlain by silty sandstone and medium-grained magnetite-bearing sandstone that also contains hornblende, chert, quartz, and feldspar. The latter intertongues with, and is overlain by, planar-bedded fine-grained sandstone devoid of trace fossils. Upward, this sandstone contains lenses of mudstone that display traces of plant rootlets. Telegraph Creek Formation Interbedded dark gray mudstone and shale, and clayey and silty fine-grained sandstone. The sandstone content increases upward. Trace fossils common on and within sandstone beds. Combined thickness 75-135 m (250-450 ft).

Kco **Cody Shale** (Late Cretaceous)—*Elkhorn Mountains* (upper black shale unit of Klepper and others, 1971; Smedes, 1966). Dark gray to black fissile shale and in the lower part, thin interbeds of very fine grained sandstone and siltstone. Spheroidal, brown-weathering limestone concretions 2-3 dm (8-12 in.) in diameter are locally abundant in the shale, and thin layers rich in feldspar crystals are interbedded in the uppermost part. Thickness 20-40 m (60-130 ft).

Kfm **Frontier and Mowry Formations**, **undivided** (Late and Early Cretaceous)—*Elkhorn Mountains* (middle siliceous mudstone and sandstone unit of Klepper and others, 1971; Smedes, 1966). Frontier Formation Light gray, medium-grained quartz-chert (salt-and-pepper) sandstone and olive gray, very fine grained to fine-grained thinly laminated sandstone, and subordinate siltstone, shale and conglomerate; Mowry Formation Olive and dark to light gray, siliceous mudstone interbedded with olive to gray mudstone, siltstone, and subordinate sandstone underlain by flaggy olive gray to medium light gray, fine-grained sandstone. Relatively clean sandstone at base. Thickness 175-285 m (580-930 ft).

Kmdt **Muddy and Thermopolis Formations**, undivided (Early Cretaceous)—*Elkhorn Mountains* (lower black shale unit of Klepper and others, 1971; Smedes, 1966). Muddy Formation Dark, fine-grained, argillaceous and carbonaceous sandstone with interbeds of siltstone and shale; Thermopolis Formation Dark gray to grayish black, fissile shale and silty shale that contains many thin beds of olive and gray siltstone. Roughly spheroidal calcareous concretions as much as 18 inches in diameter that weather to a rusty color are sporadically present. Basal clean quartz and subordinate chert orthoquartzite with well-sorted interlocked grains. Thickness 65-150 m (215-500 ft).

Kk **Kootenai Formation** (Early Cretaceous)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Upper: Gray limestone interbedded with dark shale and siltstone or red siltstone; Middle: Dominantly red shale and mudstone or claystone, and green or greenish gray siltstone. Lower: Coarse- to medium-grained, speckled quartz-chert (salt-and-pepper) sandstone. Thickness 135-165 m (445-540 ft).

KJm **Morrison Formation** (Early Cretaceous and Late Jurassic)—*Big Belt Mountains* (Reynolds and Brandt, 2005). Greenish gray to grayish red siltstone and minor mudstone, thin grayish orange sandstone, discontinuous silty and clayey limestone beds that contain sand grains, charophytes, and possible algal filaments. Includes grayish black coaly siltstone and low-grade coal interval about 2-4 m (6.5-13 ft) thick at top which has yielded Cretaceous palynomorphs. Thickness 65 m (215 ft).

Jm **Morrison Formation** (Late Jurassic)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Olive brown, purple, and varicolored shale, mudstone, siltstone, fine-grained sandstone, and limestone. Red shale and mudstone relatively abundant in some places. Thickness 130-170 m (425-550 ft).

Jms **Morrison and Swift Formations**, undivided (Jurassic)

Jsw **Swift Formation** (Jurassic)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Brown and brownish yellow, friable, highly calcareous cherty sandstone speckled with limonite. In places, one or more beds near the base are crowded with broken oyster shells. Basal conglomerate as much as 1 m (3 ft) thick of chert pebbles and cobbles in matrix of medium- to coarse-grained sandstone present at many localities. Thickness 5-15 m (15-50 ft).

Pp **Phosphoria Formation** (Permian)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Chert quartzitic sandstone, and limestone, locally with a few thin beds of phosphatic quartzite. Thickness 40 m (125 ft).

IPq **Quadrant Formation** (Pennsylvanian)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Very light gray quartzitic sandstone that alternates with light-gray dolomite or limestone. Typically, one or two ledge-forming beds of massive quartzite as much as 25 ft thick in upper 100 ft. Some quartzite beds conspicuously crossbedded and some also conspicuously spotted. Thickness 100-120 m (330-400 ft). *Spokane Hills* (Mertie and others, 1951, [equivalent to their upper Quadrant Formation]): Light gray to light pink, brownish-weathering, hard, tough, brittle with dense to glassy appearance.

IPMa **Amsden Formation** (Pennsylvanian and Mississippian)— *Elkhorn Mountains* (Smedes, 1966). Grayish red to pale grayish red, thin-bedded siltstone with thin beds of pale red purple and pale yellowish gray dolomite near middle of formation. Thickness about 55 m (180 ft).

IPMsr **Snowcrest Range Group** (Pennsylvanian and Mississippian)— *Spokane Hills* (Lower Quadrant Formation of Mertie and others, 1951). Amsden Formation–red mudstone and subordinate gray limestone; underlain by Tyler Formation equivalent tightly cemented, resistant, fine-grained, clean sandstone; underlain by Lombard Limestone–light gray crinoidal, thinly and irregularly-bedded limestone; underlain by Kibbey Formation–grayish red, fine-grained, clean quartz sandstone. Thickness about 60 m (200 ft).

Mho **Heath and Otter Formations** (Mississippian)—*Big Belt Mountains* (Reynolds and Brandt, 2005). Upper: Medium gray, to dominantly medium dark gray and dark olive gray mudstone and silty mudstone with thin beds of light gray and yellowish gray sandy limestone and dolostone. Middle: Light brownish gray to olive gray, laminated and very thin bedded silty mudstone and very thin limestone, dolostone, and sparse dolomitic sandstone beds. Lower: Light green, pale greenish gray and grayish green to olive gray mudstone, locally oölitic and with concentrically banded algal colonies. Thickness of map unit 230-335 m (755-1,000 ft).

Mm **Madison Group**, undivided (Mississippian)

Mmc **Mission Canyon Limestone** (Mississippian)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Medium to light gray or pale grayish yellow, fine- to coarse-crystalline limestone with thin layers of gray chert. One or more zones of solution breccia in upper part with siltstone or shale matrix. Thickness 245-300 m (800-1,000 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Light gray to dark gray, massive, poorly bedded fine-grained to coarse-grained, fossiliferous limestone. Altered to coarse-crystalline marble in Spokane Hills.

Ml **Lodgepole Limestone** (Mississippian)—*Elkhorn Mountains* (Klepper and others, 1971; Smedes, 1966). Medium gray and light gray, thin-bedded limestone that is primarily lithified carbonate sand. Some darker dolomite beds in lower half. Many beds fossiliferous and have fetid odor. Thickness about 215-245 m (700-800 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Dominantly bluish gray (Spokane Hills) or light gray (Big Belt Mountains), but locally dark gray, bluish gray, brown, or red, thinly bedded, locally fossiliferous limestone that weathers buff or reddish brown. Contains some light colored chert and minor yellow and reddish soft, fine-grained, thin-bedded, fine-grained sandstone.

MDtm **Three Forks, Jefferson, and Maywood Formations**, undivided (Mississippian and Devonian)

MDt **Three Forks Formation** (Mississippian and Devonian)—*Elkhorn Mountains* (Klepper and others, 1971). Dark gray, greenish gray, and brown shale with fossiliferous, argillaceous gray limestone 10 to 25 ft above base. Thickness 90 m (300 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Drab to purplish gray, poorly bedded shale that weathers dark gray to brownish with abundant limonitic stains locally pseudomorphic crystals of limonite after pyrite are common. Some micaceous, calcareous, or silty with poorly preserved fossils. In the Spokane Hills, the upper 30 to 50 ft is a marker bed dominantly of light gray, yellowish gray, or light green thinly bedded, dense and hard siliceous shale. Thickness about 90 m (300 ft).

MDtj **Three Forks and Jefferson Formations**, undivided (Mississippian and Devonian)

Dj **Jefferson Formation** (Devonian)—*Elkhorn Mountains* (Klepper and others, 1971). Dark brownish gray and gray fetid limestone and dolomite with a few thin beds of intraformational pebble conglomerate. Upper: Faintly mottled. Lower: A few thin layers of chert and partings of yellowish gray mudstone. Thickness 145-220 m (475-725 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Light gray or bluish black (Spokane Hills) or dark gray to brown (Big Belt Mountains), medium-grained, evenly bedded, granular-textured, locally brecciated, dolomitic limestone, part of which has a strongly fetid or oily odor when freshly broken. Minor light gray chert on some bedding planes. Forms hogbacks. Thickness 120-150 m (400-500 ft).

Dm **Maywood Formation** (Devonian)—*Elkhorn Mountains* (Klepper and others, 1971). Gray and yellowish brown silty dolomite and dolomitic or calcareous siltstone and shale. Equivalent to Dry Creek Shale of Mertie and others (1951) in Spokane Hills and Big Belt Mountains where it is poorly exposed brownish somewhat sandy and micaceous shale. Thickness 12-15 m (40-50 ft).

Ꞓpi **Pilgrim Limestone** (Cambrian)—*Elkhorn Mountains* (Klepper and others, 1971). Upper: Light and dark gray medium-bedded, partly oolitic, mottled, dolomite. Middle: Gray limestone with mottles and ribbons of yellowish gray silty dolomite Lower: Bluish gray oölitic and pebbly dolomite that weathers mottled light and dark gray. Thickness 145 m (480 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Light gray and dark gray mottled, generally massive to poorly bedded, fine- to medium-grained dolomitic

limestone with granular texture. Thinly bedded near top and base. Thickness 150 m (500 ft).

Ꞓp **Park Shale** (Cambrian)—*Elkhorn Mountains* (Klepper and others, 1971). Olive green, gray, and brown shale with a few thin beds of argillaceous limestone, siltstone, and silty sandstone. Thickness 65 m (215 ft).

Spokane Hills and Big Belt Mountains (Mertie and others, 1951). Gray to greenish gray thin-bedded, micaceous, limonitic, silty shale. Thickness 30-90 m (100-300 ft).

Ꞓm **Meagher Limestone** (Cambrian)—*Spokane Hills and Big Belt Mountains* (Mertie and others, 1951). Gray, light gray, and bluish gray, thinly and unevenly bedded, fine-grained limestone with thin discontinuous layers of light gray to bright yellow or red limestone near top and base, fragments of which occur within limestone beds, suggesting intraformational conglomerate. Thickness generally 90 m (300 ft).

Ꞓw **Wolsey Shale** (Cambrian)—*Spokane Hills and Big Belt Mountains* (Mertie and others, 1951). Grayish green, micaceous shale and discontinuous brown sandstone with crinkled bedding surfaces with mudcracks and trace fossils. Bluish gray, thin, glauconitic, rarely oölitic limestone beds in upper part. Thickness averages 120 m (400 ft).

Ꞓf **Flathead Formation** (Cambrian)—*Spokane Hills and Big Belt Mountains* (Mertie and others, 1951). Pale gray medium- to coarse-grained, hogback-forming, brittle quartzite, with irregularly distributed finely conglomeratic beds. Lacks basal conglomerate present in other areas. Small-scale cross faults are abundant. Thickness averages 60 m (200 ft).

Zd **Diorite** (Neoproterozoic)—*Big Belt Mountains* (Lonn and McDonald, 2003; Reynolds and Brandt, 2005). Greenish black, dark olive gray to predominantly olive black medium- and coarse-grained hornblende diorite and poikilitic gabbro in sill-like bodies that appear to cut section at low angles. Friable weathering.

Yh **Helena Formation** (Mesoproterozoic)—*Big Belt Mountains* (Mertie and others, 1951). Gray, thinly and unevenly bedded, commonly laminated, fine-grained to dense dolomitic limestone with thin partings of shaly limestone or calcareous shale between some beds. Thickness 0-150 m (0-500 ft).

Ye **Empire Formation** (Mesoproterozoic)—*Spokane Hills and Big Belt Mountains* (Mertie and others, 1951). Light to dark greenish gray, hard, dense, siliceous shale or argillite that is thinly bedded and banded. Some red shale in lower 60 m (200 ft) that is transitional with Spokane Formation. Thickness 245-300 m (800-1,000 ft).

Ys **Spokane Formation** (Mesoproterozoic)—*Spokane Hills and Big Belt Mountains* (Mertie and others, 1951). Bright red or greenish, soft, poorly bedded shale with subordinate siltstone in lower part. Weathers to small chips and flakes that resist abrasion. Thickness 460-610 m (1,500-2,000 ft).

Yg **Greyson Formation** (Mesoproterozoic)—*Big Belt Mountains* (Mertie and others, 1951). Dominantly dark gray to dark brown shale, siltstone, or fine-grained sandstone that

weathers dark brown or dark red. Light brown, light gray, red, or white, medium- to coarse-grained sandstone that may be conglomeratic in upper few hundred feet. Thickness 610-915 m (2,000-3,000 ft).

Yn **Newland Formation** (Mesoproterozoic)—*Big Belt Mountains* (Mertie and others, 1951). Dark gray, uniformly dense, dolomitic limestone that is thinly and evenly bedded except in upper part where thin beds of bluish gray limestone are typical. Float is brown platy fragments. Exposed thickness about 610 m (2,000 ft).

References Cited

Anderson, L.W., and LaForge, Roland, 2003, Seismotectonic study for Canyon Ferry Dam, Missouri River Basin Project, Montana: Denver, CO, U.S. Bureau of Reclamation Seismotectonics and Geophysics Group, Seismotectonic Report 2003-1, 70 p.

Becraft, G.E., 1958, Uranium in carbonaceous rocks in the Townsend and Helena valleys, Montana: U.S. Geological Survey Bulletin 1046-G, plate 4, scale 1:24,000.

CoBabe, E.A., Chamberlain, K.R., Ivie, M.A., and Giersch, J.J., 2002, A new insect and plant Lagerstätte from a Tertiary lake deposit along the Canyon Ferry Reservoir, southwestern Montana: Rocky Mountain Geology, v. 37, no. 1, p. 13-30.

Freeman, V.L., Ruppel, E.T., and Klepper, M.R., 1958, Geology of part of the Townsend Valley, Broadwater and Jefferson Counties, Montana: U.S. Geological Survey Bulletin 1042-N, p. 481-556.

Gualtieri, J.L., 1975, Preliminary unedited geologic map of the Confederate Gulch area, Broadwater and Meagher Counties, Montana: U.S. Geological Survey Open-File Report 75-211, scale 1:48,000.

Klepper, M.W., Ruppel, E.T., Freeman, V.L., and Weeks, R.A., 1971, Geology and mineral deposits, east flank of the Elkhorn Mountains, Broadwater County, Montana: U.S. Geological Survey Professional Paper 665, Plate 1, scale 1:48,000.

Le Bas, M.J., Streckeisen, A.L., 1991, The IUGS systematics of igneous rocks: Journal Geological Society of London, v. 148, p. 825-833.

Lonn, J.D., and McDonald, Catherine, 2003, Preliminary geologic map of the Hellgate Gulch 7.5-minute quadrangle, western Montana: Montana Bureau of Mines and Geology Open-File Report 482, scale 1:24,000.

Lyden, C. J., 2005, Gold placers of Montana: Montana Bureau of Mines and Geology Reprint 6, 120 p.

Mertie, J.B., Fisher, R.P., and Hobbs, S.W., 1951, Geology of the Canyon Ferry quadrangle, Montana: U.S. Geological Survey Bulletin 972, Plate 1, scale 1:48,000.

Nelson, W.H., 1963, Geology of the Duck Creek Pass quadrangle: U.S. Geological Survey Bulletin 1121-J, Plate 1, scale 1:62,500.

Pardee, J.T., and Schrader, F.C., 1933, Metalliferous deposits of the greater Helena mining region, Montana: U.S. Geological Survey Bulletin 842, plate 15, scale 1:63,360.

Reynolds, M.R., and Brandt, T.R., 2006, Preliminary geologic map of the Townsend 30' x 60' quadrangle, Montana: U.S. Geological Survey Open-File Report 2006-1138, Version 1.0, scale 1:100,000.

Reynolds, M.R., and Brandt, T.R., 2005, Geologic map of the Canyon Ferry Dam 30' x 60' quadrangle: U.S. Geological Survey Scientific Investigations Map 2860, 32 p., scale 1:100,000.

Robinson G.D., 1967, Geologic map of the Toston quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-486, scale 1:24,000.

Smedes, H.W., 1966, Geology and igneous petrology of the northern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U.S. Geological Survey Professional Paper 510, Plate 1, scale 1:48,000.

Stickney, M.C., 1987, Quaternary geologic map of the Helena valley, Montana: Montana Bureau of Mines and Geology Geologic Map Series GM-46, scale 1:50,000.

Stickney, M.C., Haller, K.M., and Machette, M.N., 2000, Quaternary faults and seismicity in western Montana: Montana Bureau of Mines and Geology Special Publication 114, scale 1:750,000.

Tysdal, R.G., 2000, Revision of the Cretaceous Slim Sam Formation, Elkhorn Mountains area, Montana: U.S. Geological Survey Professional Paper 1601-B, 8 p.

White, T.E., 1954, Preliminary analysis of the fossil vertebrates of the Canyon Ferry Reservoir area: U.S. National Museum, Proceedings, v. 103, no. 3326, p. 395-438.

Additional References

Berg, R.B., and Cox, B.E., 2001, Zeolite occurrences in western Montana with particular emphasis on the Grasshopper Creek deposit: Montana Bureau of Mines and Geology Bulletin 132, 46 p.

Davis, W.E., Kinoshita, W.T., and Smedes, H.W., 1963, Bouguer gravity, aeromagnetic, and generalized geologic map of the East Helena and Canyon Ferry quadrangles and part of the Diamond City quadrangle, Lewis and Clark, Broadwater, and Jefferson Counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-444, scale 1:62,500.

Johns, W.M., Straw, W.T., Bergantino, R.N., Dresser, H.W., Hendrix, T.E., McClernan, H.G., Palmquist, J.C., and Schmidt, C.J., 1982, Neotectonic features of southern Montana east of 112°30' west longitude: Montana Bureau of Mines and Geology Open-File Report 91, 79 p., 2 sheets.

Kinoshita, W.T., Davis, W.E., Smedes, H.W., and Nelson, W.H., 1964, Bouguer gravity, aeromagnetic, and generalized geologic map of Townsend and Duck Creek Pass quadrangles, Broadwater County, Montana: U.S. Geological Survey Geophysical Investigations Map GP-439, scale 1:62,500.

Pardee, J.T., 1925, Geology and ground-water resources of the Townsend Valley, Montana: U.S. Geological Survey Water Supply Paper 539, 61 p.

Reynolds, M.W., 1977, Character and extent of basin-range deformation at the east end of the Lewis and Clark line, Montana: Geological Society of America Abstracts with Programs, v. 9, no. 6, p. 758-759.

Reynolds, M.W., 2004, Terminus of the Montana disturbed belt and the origin of the Helena structural salient: Geological Society of America *Abstracts with Programs*, v. 36, no. 5, p. 545.

Rhoades, M.J., 1993, Structural deformation at the east end of the Lewis and Clark Line near Helena, Montana: Reactivation of a fold and thrust belt, *in* Childs, J.F., and Lageson, D.R., eds., Economic and regional geology of the Tobacco Root-Boulder Batholith region, Montana, Tobacco Root Geological Society Eighteenth Annual Field Conference Guidebook: Northwest Geology, v. 22, p. 55-56.

Schmidt, R.G., 1986, Geology, earthquake hazards, and land use in the Helena area, Montana—a review: U.S. Geological Survey Professional Paper 1316, 64 p.

Stickney, M.C., 1987, Quaternary geology and seismicity of the Helena valley, Montana: Montana Bureau of Mines and Geology Special Publication 95, p. 49-52.

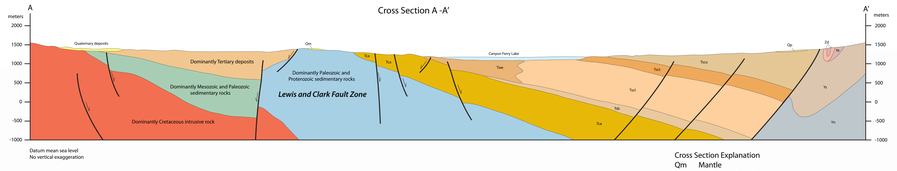
Stickney, M.C., and Bartholomew, M.J., 1987, Seismicity and late Quaternary faulting of the northern Basin and Range province, Montana and Idaho: Bulletin of the Seismological Society of America, v. 77, p. 1602-1625.

Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in western Montana: U.S. Geological Survey Open-File Report 75-285, 36 p., 1 sheet, scale 1:500,000.

Woodward, L.A., 1982, Tectonic map of the fold and thrust belt and adjacent areas, west-central Montana: Montana Bureau of Mines and Geology, Geologic Map 30, scale 1:250,000.

Zeihen, L.G., 1987, Sapphire deposits of the Helena, Montana area: Montana Bureau of Mines and Geology Special Publication 95, p. 59-60.

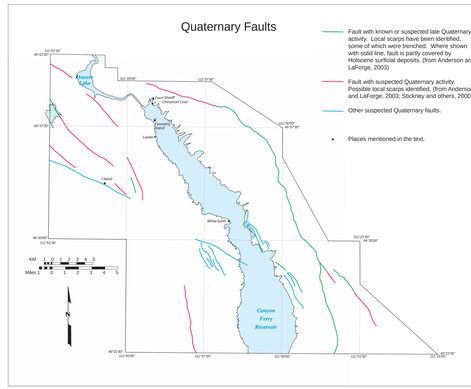
Cross Section A -A'



Cross Section Explanation

Qm	Mantle
Qp	Pediment deposit
Tscu	Sixmile Creek Formation, upper
Tsct	Sixmile Creek Formation, Toston member
Tscl	Sixmile Creek Formation of Robinson (see text)
Twe	White Earth formation
Tdc	Dunbar Creek Formation
Tca	Climbing Arrow Formation
Zd	Diorite
Ye	Empire Formation
Ys	Spokane Formation
Yn	Newland Formation

Quaternary Faults



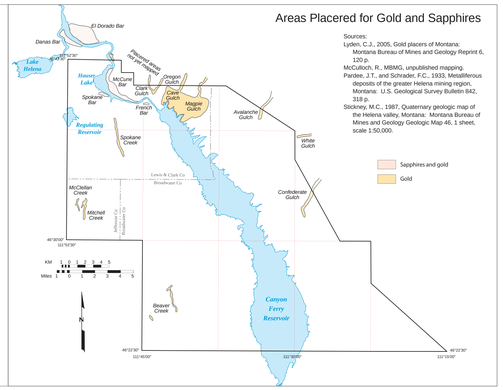
Fault with known or suspected late Quaternary activity. Local scarps have been identified, some of which were trenched. Where shown with solid line, fault is partly covered by Holocene surficial deposits. (from Anderson and LaForge, 2003)

Fault with suspected Quaternary activity. Possible local scarps identified. (from Anderson and LaForge, 2003; Stickney and others, 2000)

Other suspected Quaternary faults.

Places mentioned in the text.

Areas Placered for Gold and Sapphires



Sources:
Lyden, C.J., 2005, Gold placers of Montana: Montana Bureau of Mines and Geology Reprint 6, 120 p.
McCulloch, R., MBMG, unpublished mapping.
Pardee, J.T., and Schrader, F.C., 1933, Metalliferous deposits of the greater Helena mining region, Montana: U.S. Geological Survey Bulletin 842, 318 p.
Stickney, M.C., 1987, Quaternary geologic map of the Helena valley, Montana: Montana Bureau of Mines and Geology Geologic Map 46, 1 sheet, scale 1:50,000.

Sapphires and gold
Gold

MAP UNITS

Qal	Alluvium	Tgr	Tertiary gravel	KJm	Morrison Formation, Big Belt Mountains
Qac	Alluvium and colluvium, undivided	Ts	Sediment or sedimentary rocks, undivided	Jm	Morrison Formation, Elkhorn Mountains
Qls	Landslide deposit	Tscu	Sixmile Creek Formation, upper	Jms	Morrison and Swift Formations, undivided
Qpa	Paludal deposit	Tsct	Sixmile Creek Formation, Toston member	Jsw	Swift Formation
Qe	Eolian deposit	Tscl	Sixmile Creek Formation, lower (of Robinson, see text)	Pp	Phosphoria Formation
Qec	Eolian and colluvial deposits	Twe	White Earth map unit	Pq	Quadrant Formation
Qgr	Gravel	Tdc	Dunbar Creek Formation	PMa	Amsden Formation
Qta	Talus deposit	Tca	Climbing Arrow Formation	PMsr	Snowcrest Range Group
Qaf	Alluvial-fan deposit	Tql	Quartz latite	Mho	Heath and Otter Formations, undivided
Qaf5	Alluvial-fan deposit, youngest	TKm	Mafic intrusive rocks	Mm	Madison Group, undivided
Qaf4	Alluvial-fan deposit	Ki	Intrusive rocks, undivided	Mmc	Mission Canyon Limestone
Qaf3	Alluvial-fan deposit	Kia	Intrusive rock, augite phenocrysts	Ml	Lodgepole Limestone
Qaf2	Alluvial-fan deposit, second oldest	Kih	Intrusive rock, hornblende phenocrysts	MDtm	Three Forks, Jefferson, and Maywood Formations, undivided
Qaf1	Alluvial fan deposit, oldest	Kio	Intrusive rock, olivine phenocrysts	MDt	Three Forks Formation
Qbaf	Alluvial-fan deposit with abundant boulders	Kemma	Elkhorn Mountain Volcanics, middle unit welded tuff	MDj	Three Forks and Jefferson Formations, undivided
Qalb	Alluvium with abundant boulders	Kemtu	Elkhorn Mountain Volcanics, middle unit tuff	Dj	Jefferson Formation
Qat	Alluvial terrace deposit	Kemmu	Elkhorn Mountain Volcanics, middle unit, undivided	Dm	Maywood Formation
Qbac	Alluvium and colluvium with abundant boulders	Kelmt	Elkhorn Mountains Volcanics, lower unit welded tuff	Cpl	Pilgrim Limestone
Qc	Colluvium	Kmt3	Elkhorn Mountain Volcanics, lower unit tuff	Cp	Park Shale
Qdf	Debris-flow deposit	Kemlu	Elkhorn Mountain Volcanics, lower unit, undivided	Cm	Meagher Limestone
Qm	Mantle deposit	Kmz	Monzonitic lamprophyre	Cw	Wolsey Shale
Qp	Pediment deposit	Kmzd	Monzodiorite	Cf	Flathead Formation
Qpe	Pediment and eolian deposits	Kqm	Quartz monzonite	Zd	Diorite
Qwi	Winston map unit	Kla	Latite	Yh	Helena Formation
Qgl	Glacial till	Kset	Slim Sam, Eagle, and Telegraph Creek Formations, undivided	Ye	Empire Formation
Qgl	Glacial lake deposit	Ket	Eagle and Telegraph Creek Formations, undivided	Ys	Spokane Formation
Qls	Landslide deposit	Kco	Cody Shale	Yg	Greyson Formation
Qts	Sediment, undivided	Kfm	Frontier and Mowry Formations, undivided	Yn	Newland Formation
		Kmdt	Muddy and Thermopolis Formations,, undivided	af	Artificial fill
		Kk	Kootenai Formation	W	Water

MAP SYMBOLS

Contact: dashed where approximately located; dotted where concealed

Fault: dashed where approximately located; dotted where concealed, bar and ball on downthrown side

Strike-slip fault: dashed where approximately located; dotted where concealed. Arrows along fault trace indicate relative strike-slip displacement

Thrust fault: teeth on upthrown block; dashed where approximately located; dotted where concealed

Syncline: showing trace of axial plane and plunge direction where known; dotted where concealed

Anticline: showing trace of axial plane and plunge direction where known; dotted where concealed

Overturned syncline: Showing trace of axial plane and direction of bedding dip; dashed where approximately located, dotted where concealed

Overturned anticline: showing trace of axial plane and direction of bedding dip; dashed where approximately located, dotted where concealed

32 Strike and dip of inclined beds

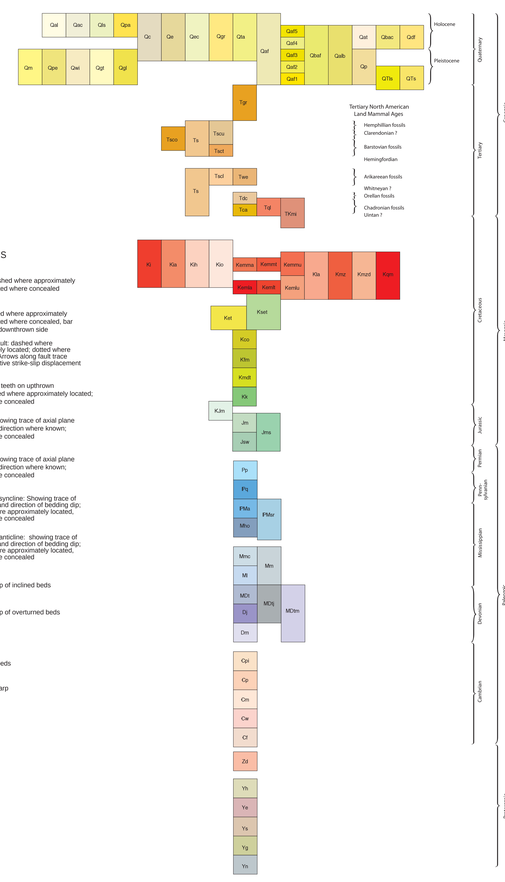
75 Strike and dip of overturned beds

Sill

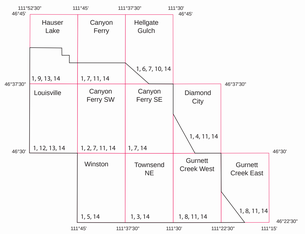
Ash bed or beds

Erosional scarp

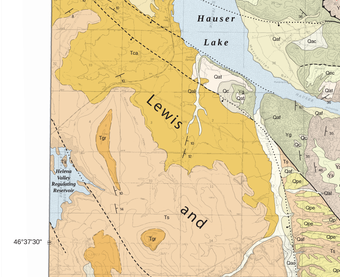
CORRELATION DIAGRAM



Sources of Geologic Mapping



1. Anderson and LaForge, 2003, figure 3.
2. Becraft, 1958, plate 4, scale 1:24,000.
3. Freeman, Ruppel, and Klepper, 1958, plate N, scale 1:48,000.
4. Gualtieri, 1975, scale 1:48,000.
5. Klepper, Ruppel, Freeman, and Weeks, 1971, plate 1, scale 1:48,000.
6. Lonn and McDonald, 2003, scale 1:24,000.
7. Mertie, Fisher, and Hobbs, 1951, plate 1, scale 1:48,000.
8. Nelson, 1963, plate 1, scale 1:62,500.
9. Pardee and Schrader, 1933, plate 15, scale 1:63,360.
10. Reynolds and Brandt, 2006, scale 1:100,000.
11. Reynolds and Brandt, 2005, scale 1:100,000.
12. Smedes, 1966, plate 1, scale 1:48,000.
13. Stickney, 1987, scale 1:50,000.
14. Stickney and others, 2000, scale 1:100,000.



Location of map area and index of 7.5' quadrangles.

Base reduced to 1:50,000 scale from U.S. Geological Survey 7.5' (1:24,000 scale) topographic quadrangles:

7.5' Quadrangle	Date	Projection	UTM Zone	Contour Interval	Declination UTM	Declination Magnetic N	Vertical Datum NGVD	Horizontal Datum NAD
Gurnett Creek East	1986	Lambert Conformal Conic	12	40	0°14'W	1986 16°E	1929	1927
Gurnett Creek West	1986	Lambert Conformal Conic	12	20	0°19'W	1986 16°30' E	1929	1927
Townsend NE	1986	Lambert Conformal Conic	12	20	0°24'W	1986 16°30' E	1929	1927
Winston	1986	Lambert Conformal Conic	12	40	0°30'W	1986 16°30' E	1929	1927
Diamond City	1966	Polyconic	12	40	0°19'W	1966 18° E		1927
Canyon Ferry SE	1972	Lambert Conformal Conic	12	20	0°24'W	1972 18° E	1929	1927
Canyon Ferry SW	1972	Lambert Conformal Conic	12	40	0°30'W	1972 18° E	1929	1927
Louisville	1985	Lambert Conformal Conic	12	20	0°31'W	1985 16°30' E	1929	1927
Heligate Gulch	1972	Lambert Conformal Conic	12	40	0°25'W	1972 18° E	1929	1927
Canyon Ferry	1972	Lambert Conformal Conic	12	40	0°30'W	1972 18° E	1929	1927
Hauser Lake	1972	Lambert Conformal Conic	12	40	0°35'W	1972 18°30' E	1929	1927

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SCALE: 1:50,000

KILOMETERS 1 0 1 2 3 4 5
MILES 1 0 1 2 3 4 5

Varied contour interval, see quadrangle table for individual contour intervals.

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G09AC00186. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.

Montana Bureau of Mines and Geology
Open-File 607

Geologic Map of the Canyon Ferry Lake area West Central Montana

Susan M. Vuke

2011