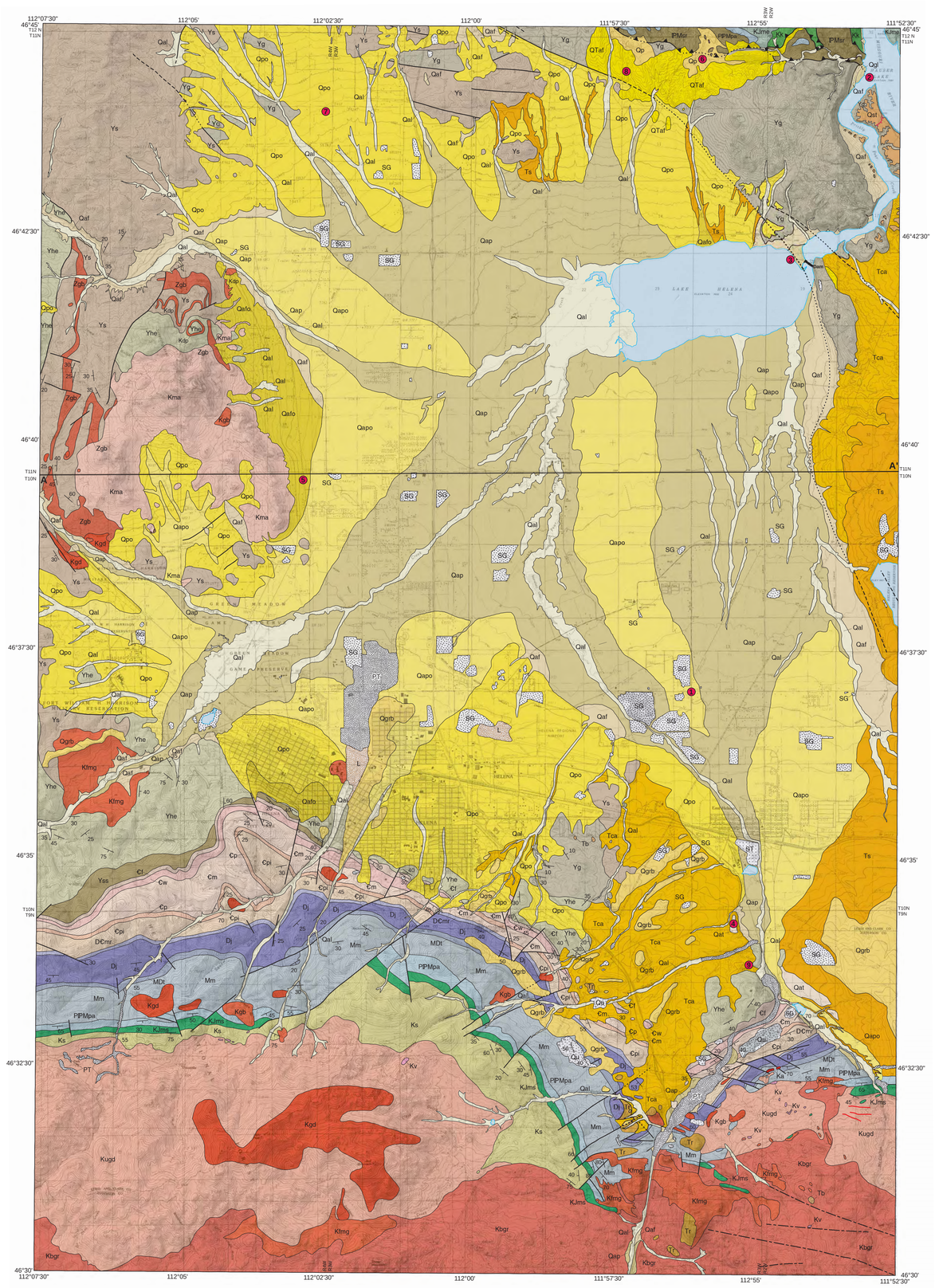


Base maps from USGS 1:24,000 scale
Quadrangles reduced to 1:50,000 scale

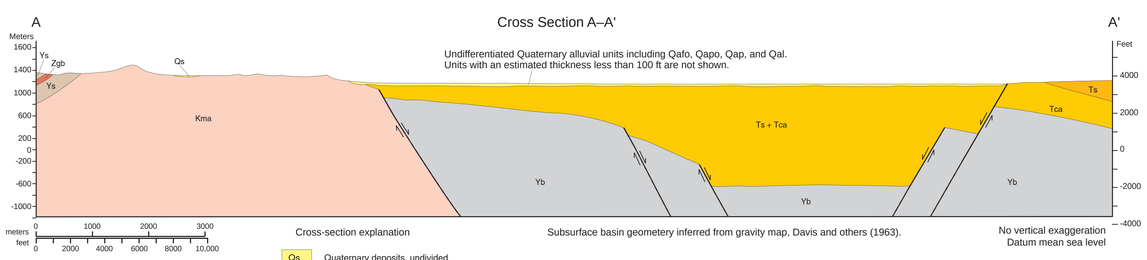
N

KILOMETERS 1 0 1 2 3 4 5

MILES 1 0 1 2 3 4 5

SCALE: 1:50,000

Cross Section A–A'



SCALE: 1:50,000

Cross-section explanation

Subsurface basin geometery inferred from gravity map, Davis and others (1963).

No vertical exaggeration
Datum mean sea level

- Qs — Quaternary deposits, undivided
- Ts — Tertiary deposits, undivided
- Tca — Climbing Arrow Formation
- Kma — Mafic rocks
- Zgb — Gabbro
- Ys — Spokane Formation
- Yb — Belt Supergroup rocks, undivided

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4167 Fax: (406) 496-4451
http://www.mbmg.mtech.edu

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

MAP UNITS

- Qal — Alluvium
- Qaf — Alluvial fan deposit
- Qap — Alluvial plain deposit
- Qapo — Alluvial plain deposit, older
- Qst — Strath terrace deposit
- Qat — Alluvial terrace deposit
- Qafo — Alluvial fan deposit, older
- Qp — Pediment deposit
- Qgl — Glacial lake deposit
- Qpo — Pediment deposit, older
- Qgrb — Gravel, bouldery
- QTaf — Alluvial fan deposit
- Ts — Sediment and sedimentary rock, undivided
- Tca — Climbing Arrow Formation
- Tr — Rhyolite
- Tb — Basalt
- Ka — Alaskite and aplite
- Klmg — Felsic monzogranite
- Kbgr — Butte Granite
- Kugd — Unionville Granodiorite
- Kgd — Granodioritic rocks
- Kgb — Gabbro
- Kdp — Diorite porphyry
- Kma — Mafic rocks
- Kv — Volcanic rocks, undivided
- Ks — Sedimentary rock, metamorphosed, undivided
- Kk — Kootenai Formation
- KJms — Morrison and Swift Formations, undivided
- KJme — Morrison Formation and Ellis Group, undivided
- PPMpa — Phosphoria, Quadrant and Amsden Formations, undivided
- PMsr — Snowcrest Range Group
- Mm — Madison Group, undivided
- MDt — Three Forks Formation
- Dj — Jefferson Formation
- DCmr — Maywood and Red Lion Formations, undivided
- Cpi — Pilgrim Formation
- Cp — Park Formation
- Cm — Meagher Formation
- Cw — Wolsey Formation
- Cf — Flathead Formation
- Zgb — Gabbro
- Yss — Shepard and Snowslip Formations, undivided
- Yhe — Helena and Empire Formations, undivided
- Ys — Spokane Formation
- Yg — Greyson Formation

Manmade

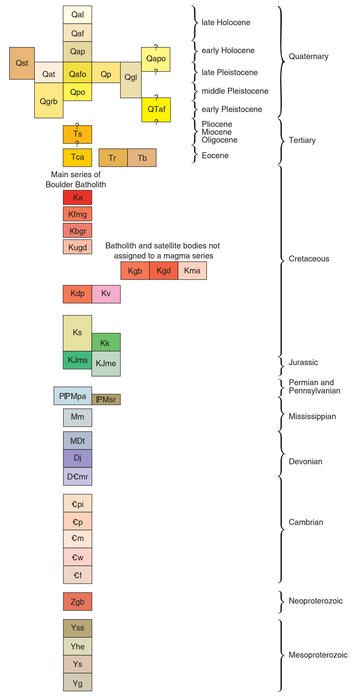
- L — Landfill
- PT — Placer Tailings
- SG — Sand and gravel pit
- ST — Smelter tailings
- Qu — Quarry
- Dam
- Water

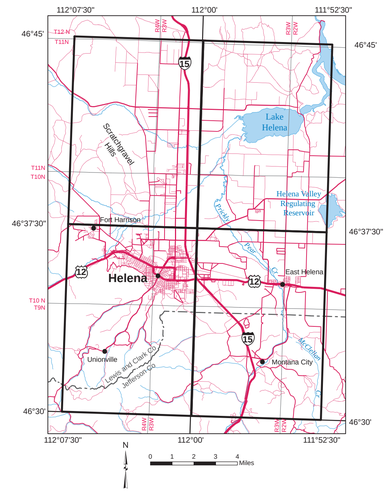
For a more detailed description of the map units and symbols, please refer to the text accompanying this map.

MAP SYMBOLS

- Contact
- Fault: dashed where approximately located; dotted where concealed
- Thrust fault: dotted where concealed
- Linear feature
- Riser between strath terrace with different elevations
- Strike and dip of inclined beds (55)
- Dike
- Location of good exposure or example of unit. Locality numbers indicated in Description of Map Units in text pamphlet.

CORRELATION CHART





Scratchgravel Hills
Base map produced by the United States Geological Survey
Control by: USGS, NOS/NOAA
Compiled from aerial photographs taken: 1978
Field checked: 1980
Map edited: 1985
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 0°46' West
1985 Magnetic NorthDeclination: 17° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

Contour Interval: 20 ft

Helena
Base map produced by the United States Geological Survey
Control by: USGS, NOS/NOAA
Compiled from aerial photographs taken: 1978
Field checked: 1980
Map edited: 1985
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 0°46' West
1985 Magnetic NorthDeclination: 17° East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

Contour Interval: 40 ft

Lake Helena
Base map produced by the United States Geological Survey
Control by: USGS, USC&GS, and Missouri River Commission
Compiled from aerial photographs taken: 1970
Field checked: 1972

Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 0°41' West
1972 Magnetic NorthDeclination: 18°30' East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

Contour Interval: 20 ft

East Helena
Base map produced by the United States Geological Survey
Control by: USGS, NOS/NOAA
Compiled from aerial photographs taken: 1978
Field checked: 1980
Map edited: 1985
Projection: Lambert Conformal Conic
Grid:1000 meter Universal Transverse Mercator Zone 12
UTM grid declination: 0°41' West
1985 Magnetic NorthDeclination: 16°30' East
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum

Contour Interval: 20 ft

MAP SOURCES

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

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MBMG
Montana Bureau of Mines and Geology

MBMG Open-File Report 689

Geologic Map of the Helena Valley, West-Central Montana

Michael C. Stickney and Susan M. Vuke

2017

GEOLOGIC MAP OF THE HELENA VALLEY, WEST-CENTRAL MONTANA

Montana Bureau of Mines and Geology Open-File Report 689

Michael C. Stickney and Susan M. Vuke

2017

The STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey provided partial support under contract number G11AC20257

GEOLOGIC MAP OF THE HELENA VALLEY
DESCRIPTION OF MAP UNITS

Qal **Alluvium** (late Holocene)—Stream-channel deposits of gray to brown, moderately sorted, pebble to cobble gravel with fine- to coarse-grained sand matrix. Clasts are well-rounded to subrounded, becoming generally smaller and better sorted toward Lake Helena. Caliche films are nonexistent and the only soil is organic matter and silt trapped along brushy creek banks and in abandoned channels.

Qaf **Alluvial-fan deposit** (late Holocene)—Gray to brown beds and lenses of sand, silt, and angular to subrounded, locally derived pebble and cobble gravel as much as 20 cm in diameter, deposited in fan and lobe-shaped deposits. Degree of sorting and rounding of clasts and geomorphic form varies widely depending on size and discharge of drainage above fan. Discontinuous eolian sand and silt layers are common within these deposits in the eastern half of the map area. These alluvial fans merge with Qal up some gullies and channels. Weak soils developed on fan surfaces generally consist of as much as 10 cm of weak caliche accumulation below the B horizon. One or more buried A horizons are frequently present.

Qap **Alluvial-plain deposit** (early Holocene)—Moderately sorted pebble to cobble gravel in a light gray to light brown silt and sand matrix. Clasts are well-rounded to subrounded, becoming generally smaller and better size-sorted toward Lake Helena, and coarser toward their source, where they grade into alluvial terrace deposits along modern streams. Deposits capped by 10–15 cm of A soil horizon over 10–20 cm of B horizon. Scattered clasts to a depth of about 20 cm have very thin irregular caliche films on bottoms.

Qapo **Alluvial-plain deposit, older** (earliest Holocene or latest Pleistocene, Pinedale equivalent?)—Moderately sorted cobble to pebble gravel in a light brown silt and sand matrix. Clasts are well-rounded to subrounded, becoming generally better sorted toward Lake Helena. Contains sand lenses as much as 30 cm thick. Approximately 40–50 percent of granitic clasts are weathered and decomposed, locally capped by as much as 1 m of loess. Elsewhere capped by a 10- to 15-cm-thick A soil horizon over 10–20 cm of B horizon. Clast bottoms coated with caliche to a depth of about 1 m below B horizon **(Locality 1)**.

Qst **Strath-terrace deposit** (Holocene and Pleistocene)—Deposit along the Missouri River composed of light gray to brown, weakly bedded, moderately well-sorted and well-rounded pebble and cobble gravel with silty sand matrix, preserved in multiple terraces as much as 75 m above the present river channel. Uppermost strath is capped by a soil that consists of 10 cm of A horizon overlying a 1-m-thick horizon of very well-developed caliche that cements the deposit. Hachured line through Qst indicates riser between strath terraces with different elevations.

Qgl **Glacial deposit** (Pleistocene, Illinoian, and Wisconsin)—Deposit of Glacial Lake Great Falls composed of brown to grayish dark brown, thinly bedded (1 mm–5

cm), fine-grained sand, silt, and clay. Some fine-grained sand layers display slight crossbedding and small symmetrical ripple marks; some muddy layers show mud cracks. Rusty iron stains coat joint fractures and bedded surfaces. Locally interbedded with silty angular pebble gravel from alluvial fans along steep bedrock hills **(Locality 2)**. Seismically induced(?) soft-sediment deformation along the north shore of Lake Helena consists of a 30- to 50-cm-thick zone of convoluted folds with wavelengths as much as 1.0 m and amplitudes as much as 30 cm. Overlying and underlying sediment is undeformed **(Locality 3)**.

Qat **Alluvial-terrace deposit** (late Pleistocene)—Deposit along McClellan and Prickly Pear Creeks that consist of moderately sorted, well-rounded to subrounded pebble and cobble gravel in a light gray to light brown silty sand matrix, situated 20–30 m above modern stream channels **(Locality 4)**.

Qafo **Alluvial-fan deposit, older (**middle to late Pleistocene)—Along the east flank of the Scratchgravel Hills and along the southern edge of the Helena Valley. Deposits are areally more extensive, but otherwise similar in composition and color to Qaf deposits. Unit is capped with a soil that consists of 15 cm of A horizon over 15 cm of B horizon that overlies a well-developed caliche horizon 0.5–1.0 thick **(Locality 5)**.

Qp **Pediment deposit** (Pleistocene)—Pediment gravel north of Lake Helena composed of light brown to tan, poorly sorted, unstratified pebble and cobble gravel with sandy silt matrix. Deposit is a lag gravel on the erosional pediment surface. Angular to subrounded pebbles reflect local bedrock lithologies **(Locality 6)**.

Qgrb **Gravel, bouldery** (early to middle Pleistocene)—Deposits south of Ft. Harrison and along the southern edge of the Helena Valley, composed of weakly stratified, poorly sorted, pebble to boulder gravel in a grayish brown to yellowish light gray, clayey and silty sand matrix. All clasts are well rounded to subrounded and range to as much as 2 m in diameter with a median size of 2–5 cm. Clasts of granitic composition are thoroughly decomposed. Well-developed soil includes as much as 10 cm of A horizon and a well-developed carbonate horizon about 1 m thick. This deposit is preserved on hilltops and ridges as remnants of formerly much more extensive deposits.

Qpo **Pediment deposit, older** (middle Pleistocene)—Gravel composed of brown, tan, and gray, poorly sorted, unstratified, pebble gravel with sandy silt matrix. Thickness 0–5 m, averaging 1–2 m. Subrounded to subangular gravel clasts reflect local bedrock lithologies. Deposit is a lag gravel on an extensive erosional pediment surface along the valley margin. Deposit displays a well-developed soil that consists of a 10–15 cm A horizon over 0.5- to 1.0-m-thick caliche horizon; locally capped with 2–10 cm of loess **(Locality 7)**.

QTaf **Alluvial-fan deposit** (early Pleistocene or late Tertiary?)—Deposits north of Lake Helena composed of reddish brown, poorly sorted, moderately stratified, pebble

to boulder gravel with clayey sand matrix. Bedding consists of 30-cm-thick beds of moderately sorted pebble gravel; 1.5-m-thick layers of subangular, boulder, and cobble gravel; 50-m-thick layers of subangular, boulder, and cobble gravel; and 50-cm-thick red, clayey sand lenses. Rounded argillite and decomposed granitic clasts as much as 70 cm in diameter and subrounded quartzite as much as 1 m in diameter constitute 70 percent of the deposit. Exposed part of deposit is at least 50 m thick. Soil is poorly developed but probably eroded; contains thin caliche coats on pebbles near surface **(Locality 8)**. May be a syntectonic deposit (?) associated with the Eldorado Thrust.

Ts **Sediment and sedimentary rock, undivided** (Tertiary)—Grayish orange to yellowish gray, and locally reddish gray fine-grained, argillaceous, micaceous sand and silt, locally moderately well cemented, with floating larger sand and granule grains with sandy pebble and cobble interbeds and lenses.

Tca **Climbing Arrow Formation** (Eocene)—
South of East Helena (Montana City area): Tan to light gray, unbedded, unsorted volcaniclastic deposits that include subangular pumice fragments as much as 4 cm in diameter, and rhyolite gravel **(Locality 9)**.
Southwest of East Helena: Poorly sorted coarse, ash-rich sand and silt with floating larger angular clasts that range from granule to cobble size and include various local lithologies, and subordinate reddish-brown mudstone.
East of Lake Helena: Well-bedded olive gray and yellowish clay; tan siltstone; light gray, poorly sorted, fine to coarse-grained arkosic sand interbeds; moderately sorted, rounded rhyolite pebble gravel; and thin lignite beds.

Tr **Rhyolite**—Ash-gray intrusive and extrusive rhyolite with phenocrysts of black quartz, sanidine, sparse plagioclase, and sparser biotite (Knopf, 1963).

Tb **Basalt (Eocene?)**—Olivine basalt identified by Knopf (1963) in one small area in the southeastern corner of map.

ROCKS OF THE MAIN MAGMA SERIES OF THE BOULDER BATHOLITH
(Smedes and others, 1988)

Ka **Intrusive rocks, undivided** (Late Cretaceous)—Alaskite and aplite (Knopf, 1963).

Kfmg **Felsic monzogranite** (Late Cretaceous)—Igneous classification from du Bray and others (2009), description modified from Reynolds and Brandt (2005), who classified unit as biotite granite. Pinkish gray and yellowish gray medium crystalline; orthoclase and microcline with minor calcium feldspar; common books and flakes of biotite; common interstitial quartz crystals; common to abundant nodules of tourmaline, and tourmaline along fractures in Montana City area. Intrudes Butte Granite (Kbgr) and Unionville Granodiorite (Kugd).

Kbgr **Butte Granite** (Late Cretaceous)—Compositionally a monzogranite with subordinate diorite following LeBas and Streckeisen (1991). Nomenclature change from Butte Quartz Monzonite to Butte Granite designated by Lund and others (2002). Description: Reynolds and Brandt (2005), who referred to unit as Butte Quartz Monzonite. Light to medium gray and light pinkish gray; homogeneous with rare, faint, planar internal structure; euhedral to subhedral plagioclase crystals partly enclosed by alkali feldspar crystals and quartz. Alkali feldspar occurs as large euhedral to subhedral poikilitic, twinned phenocrysts; quartz occurs as irregular crystals and intercrystalline masses and in graphic intergrowths with alkali feldspar; biotite occurs as euhedral books and as small isolated flakes; scattered hornblende crystals with irregular-shaped margins; rare pyroxene; accessory minerals include magnetite, ilmenite, sphene, zircon, and apatite; intruded by some aplite and pegmatite dikes; locally abundant xenoliths of diorite, welded tuff, and scattered other crystalline rocks

Kugd **Unionville Granodiorite** (Late Cretaceous)—Nomenclature from Knopf (1963), description modified from Reynolds and Brandt (2005). Medium gray and medium light gray to light olive gray, medium to finely crystalline, hypidiomorphic, with augite, biotite, hornblende, hypersthene with intercrystalline labradorite feldspar, and minor quartz and alkali feldspar; intruded by Butte Granite (Kbgr) in southwest corner of map.

BATHOLITHIC ROCKS AND SATELLITE BODIES NOT ASSIGNED TO THE MAIN MAGMA SERIES (Smedes and others, 1988)

Kgb **Gabbro** (Upper Cretaceous)—Igneous classification and description from Knopf (1963). Olivine-orthoclase gabbro rich in ferromagnesian minerals—olivine, hypersthene, augite, hornblende, and biotite.

Kgd **Granodioritic rocks** (Late Cretaceous)—Igneous classification from Smedes and others (1988), description from Reynolds and Brandt (2005), who classified unit as biotite granodiorite. Medium gray and medium light gray to light olive gray, medium to finely crystalline, hypidiomorphic with augite, biotite, hornblende, and hypersthene, intercrystalline labradorite feldspar, minor quartz, and alkali feldspar; intruded by Butte Granite (Kbgr) in southern part of map.

Kma **Mafic rocks** (Upper Cretaceous)—Igneous classification from Smedes and others (1988); Knopf (1963), who classified unit as syenodiorite of the Scratchgravel Hills stock.

Kdp **Diorite porphyry** (Late Cretaceous)—Igneous classification and description from Knopf (1963)—Stocks, sills, and dikes, in part pre-batholithic, and in part syn-batholithic. The most notable stock of pre-batholithic age forms the hill in Helena on which Carroll College stands. It intrudes the Helena Formation. It is rudely a schistose porphyry with 50 percent of white andesine phenocrysts and a few

inconspicuous crystals of hornblende or biotite enclosed in a microcrystalline groundmass.

The porphyry of the pre-batholithic sills and dikes is of the same general character as the stock at Carroll College, but darker in general, caused by abundant fine, flaky biotite disseminated throughout the porphyry by the contact-metamorphism of the Boulder Batholith. In general, the pre-batholithic dikes are more "altered" in appearance than those that were emplaced during the intrusion of the batholith. The diorite porphyry intrusives are likely correlatives of the volcanic extrusives of Early Cretaceous age (Kv).

Kv **Volcanic rocks, undivided** (Early Cretaceous)—Andesite, basalt, and rhyodacite. (Knopf, 1963).

Sedimentary rocks have been contact metamorphosed to various degrees by the Boulder Batholith. Much of the following descriptions from Knopf (1963).

Ks **Sedimentary rock, metamorphosed, undivided** (Cretaceous)—In the southern part of map area may include Cody through Kootenai Formations (Cody, Frontier, Mowry, Muddy, Thermopolis, and Kootenai Formations). Sandstone beds have diopside, tremolite, or calcic plagioclase cement due to metamorphism. Other lithologies include quartzite, hornfelsed shale and pelitic hornfels, subordinate white calcic hornfels, and a several beds of bluish gray limestone.

Kk **Kootenai Formation** (Early Cretaceous)—

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. Formation thickness 165 m (540 ft) (Smedes, 1966).

KJms **Morrison and Swift Formations, undivided** (Early Cretaceous and Late Jurassic)—Hornfels and quartzite of the metamorphosed Morrison Formation and of upper Swift Formation in the southern part of the map area. Combined thickness 98 m (320 ft) (Smedes, 1966).

KJme **Morrison Formation and Ellis Group, undivided—**

Morrison Formation—Greenish gray to grayish red siltstone and minor mudstone; thin grayish orange sandstone; discontinuous silty and argillaceous limestone beds that contain sand grains, charophytes, and possible algal filaments. Locally includes grayish black coaly siltstone and low-grade coal interval, about 2- to 4-m thick, at top. Thickness about 65 m (213 ft) (Reynolds and Brandt, 2005).

Ellis Group

Swift Formation—Discontinuous sandstone and siltstone and thin basal conglomerate. Light olive gray to pale brownish gray, and medium to medium dark gray. Thickness 0–50 m (0–165 ft).

Sawtooth Formation—Calcareous sandstone and sandy limestone and lenticular calcareous pebble conglomerate containing oyster fossils at base. Yellowish gray to grayish orange, weathers same; cross laminated and laminated. Thickness 0–4 m (13 ft). (Reynolds and Brandt, 2005).

PPMpa **Phosphoria, Quadrant, and Amsden Formations, undivided** (Permian, Pennsylvanian, and Mississippian)—Quadrant Formation metamorphosed to flinty quartzite. Overlying Phosphoria and underlying Amsden Formations are poorly exposed (Berg, 2009).
Phosphoria Formation—Cherty quartzite and limestone. Thickness less than 6 m (20 ft).
Quadrant Formation—Flinty quartzite.
Amsden Formation—Poorly exposed siltite and dolomite
Combined thickness of Quadrant and Amsden Formations 113 m (370 ft).

PMsr **Snowcrest Range Group** (Pennsylvanian and Mississippian)—Red mudstone and subordinate gray limestone underlain by fine-grained, clean sandstone; underlain by light gray crinoidal, thinly and irregularly bedded limestone; underlain by grayish red, fine-grained, clean quartz sandstone. Thickness about 60 m (200 ft).

Mm **Madison Group, undivided** (Mississippian)—White, coarsely crystalline, thick-bedded limestone. Thickness 396 m (1300 ft).

MDt **Three Forks Formation** (Mississippian and Devonian)—Massive aphanitic white or light bluish gray scapolite-diopside calc-hornfels that overlies blue black shale, which overlies limestone and green shale. Thickness 107 m (350 ft).

Dj **Jefferson Formation** (Devonian)—Dark gray and black highly fetid, highly porous dolomite that alternates with light-colored limestone. Thickness 229 m (750 ft).

DCmr **Maywood and Red Lion Formations, undivided** (Devonian and Cambrian)
Maywood Formation (Devonian)—Red siltstone and thin-bedded limestone that are poorly exposed. Thickness 9 m (30 ft).
Red Lion Formation (Cambrian)—Interbedded limestone and dolomite with a distinctive marker bed 8–15 m (25–50 ft) thick with crinkly filaments of chert which anastomose irregularly, roughly parallel to bedding. Thickness 49 m (160 ft).

Cpi **Pilgrim Formation** (Cambrian)—Hasmark Dolomite of Knopf (1963). Upper sequence of light gray-weathering dolomite and lower part of dark gray, drab-weathering, thick-bedded dolomite, with dark mottling in patterns that range from simple to complex, 6-in white forms perpendicular to bedding with dark rims, and branching white crooked tubes. Thickness 137 m (450 ft) (Knopf, 1963).

Cp **Park Formation** (Cambrian)—Dark gray, compact, minutely grained argillite with little or no fissility. Thickness 55–61 m (180–200 ft).

Ꞓm **Meagher Formation** (Cambrian)—Upper part massive pure limestone, well exposed on Mount Helena in the western part of the Helena valley, and near East Helena where it has been quarried extensively; lower part generally metamorphosed to diopside-calcite hornfels that weathers brown. Thickness 195 m (640 ft).

Ꞓw **Wolsey Formation** (Cambrian)—Micaceous siltstone with ripple marks and worm burrows with interbeds of calc-hornfels where contact metamorphosed. Thickness 60 m (200 ft).

Ꞓf **Flathead Formation** (Cambrian)—White vitreous, coarse-grained quartzite that weathers with reddish tint; locally crossbedded and locally conglomeratic at base. Maximum thickness 52 m (170 ft).

Zgb **Gabbro** (Neoproterozoic)—Black, coarse-grained sills as much as 122 m (400 ft) thick in Belt Supergroup rocks of the Scratchgravel Hills; locally pigeonitic (Knopf, 1963).

Yss **Shepard and Snowslip Formations** (Reynolds, 2000) (Mesoproterozoic)—Marsh Formation of Knopf (1963). Pale red purple siltstone and interbedded quartzite. Abundant ripple marks, lamination, crossbedding and occasional salt casts (Knopf, 1963).

Yhe **Helena and Empire Formations, undivided** (Mesoproterozoic)

Helena Formation (Mesoproterozoic)—Medium gray to medium dark gray dolomitic limestone and limestone with partings of dolomitic siltite. Weathers grayish orange and pale grayish orange to yellowish gray; common to abundant molartooth structure; scattered small, vertically stacked, laterally linked stromatolite colonies; formation splits platy parallel to abundant fractures (Reynolds and Brandt, 2005).

Empire Formation (Mesoproterozoic)—Pale grayish green and pale olive gray argillite and siltite with very thin beds of quartzite and sandy limestone; weathers grayish green and greenish gray; some thin intervals near base weather pale red and pale reddish brown; laminated and very thin-bedded argillite and siltite. Quartzites are very light gray to white; weather same; fine- to medium-grained, very thin bedded, ripple cross-laminated, and planar small-scale cross laminae; calcareous, local silica cement; common dissolution porosity in sandstones. Limestone beds 4–20 cm thick are silty and contain fine sand. Exposed thickness about 240 m (787 ft) (Reynolds and Brandt, 2005).

Ys **Spokane Formation** (Mesoproterozoic)—Pale red and moderate reddish brown siltite and argillite, and very thin greenish gray intervals of siltite and argillite in basal 20 m (66 ft). Weathers moderate reddish brown, grayish red, and dusky red, laminated and very thin bedded, cross-laminated, locally ripple cross-laminated,

predominantly silt and clay on parting surfaces. Locally common rip-up clasts and fluid escape structures; scattered lenticular beds of fine-grained quartz arenite and calcareous quartz arenite and calcareous quartz arenite as thick as 14 cm (5.5 in); scattered beds of sandy limestone and rare stromatolitic limestone, 20–39 cm (8–15 in) thick, interbedded with greenish gray siltite in basal 45 m (150 ft). Thickness as much as 1480 m (4856 ft) (Reynolds and Brandt, 2005).

Yg **Greyson Formation** (Mesoproterozoic)—Medium olive gray, greenish gray, and medium dark gray siltite and argillitic siltite that weathers greenish gray, pale olive, olive gray, dusky yellow, and pale yellowish brown. Light pinkish gray, yellowish gray, and light gray feldspathic quartzite intervals as thick as 4 m (13 ft), grade into calcareous felspathic quartzite and sandy limestone interbedded with greenish gray to light brownish gray siltite (Reynolds and Brandt, 2005).

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