

**GEOLOGIC MAP OF THE LIVINGSTON 30' x 60' QUADRANGLE
SOUTH-CENTRAL MONTANA**

By

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Discussion

An attempt was made in the Livingston quadrangle to preserve as much detail as possible at a scale of 1:100,000 from earlier maps at larger scales. Also stratigraphic units used by previous authors were maintained, even though they were not necessarily consistent from one map to another. For example, the Upper Cretaceous Livingston Group as described by Roberts (1963) consists in descending order of the Hoppers, Billman Creek, Miner Creek, and Cokedale Formations. North of Roberts' maps, Skipp and others (1999) mapped and described the Sedan Formation, also of Upper Cretaceous age, in the same stratigraphic position as the Miner Creek and Cokedale Formations of the Livingston Group. Detailed mapping of the Sedan Formation and Livingston Group to the south should resolve this inconsistency.

The Sliderock Mountain map unit (informal map unit Klsr) includes all the volcanic rocks erupted from the Sliderock Mountain stratovolcano (du Bray and others, 1994; Lopez, 2000). These rocks are herein included in the Livingston Group because that terminology is well established in the literature. They were first recognized by Weed (1893) who applied the name Livingston Agglomerates. Parsons (1942) referred to these volcanic rocks as the Livingston igneous series, and described a volcanic source similar to that described by du Bray and others (1994). The stratigraphic relations observed during field work in the Livingston quadrangle confirm what Parsons (1942) described: that the volcanic rocks overlie the Judith River Formation and that the upper part interfingers with the Hell Creek Formation. Like Weed and Parsons, du Bray and others (1994) also included these volcanic rocks in what is now called the Livingston Group.

The Fort Union Formation is shown as both Cretaceous and Tertiary in age where it was not divided into members. Roberts (1965, p. B 60) suggests that the Cretaceous-Tertiary boundary may lie in the lower 800 ft of his middle member of the Fort Union Formation or within approximately 1800 ft of the base of this Formation in the southwestern part of the map area. Plant microfossils from this part of the Fort Union Formation suggest an age range that is transitional between the Cretaceous and Paleocene. The Tongue River, Lebo, and Tullock Members of the Fort Union Formation were mapped separately in the Big Timber 30' x 60' quadrangle adjacent to the east side of the Livingston 30' x 60' quadrangle (Lopez, 2000). These three members were also mapped in the northeastern corner of the Livingston quadrangle, but in spite of a time-consuming attempt, could not be mapped to the west. It appears that the Lebo Member either pinches out to the west or is only locally preserved. Only the minimum thickness of the Fort Union Formation can be estimated in this area because the overlying Wasatch Formation was not recognized. The exposed thickness of the Fort Union Formation is estimated to be approximately 9600 ft. along the line of cross section A - A' - A". Farther to the west, an exposed thickness of approximately 8,000 ft is inferred (Skipp and others, 1999; cross section B-B').

The mechanics of emplacement of the dikes and sills and the Big Timber stock (in the Crazy Mountains just north of the Livingston quadrangle) pose an intriguing problem for further study. Dikes do not form the striking radial pattern shown on the Geologic Map of Montana (Ross and others, 1955); instead they definitely have a preferred north-northwest orientation. Also the sills seem to be concentrated in several clusters and to be more distal from the intrusive center in the Crazy Mountains than the dikes. At only two localities could the age

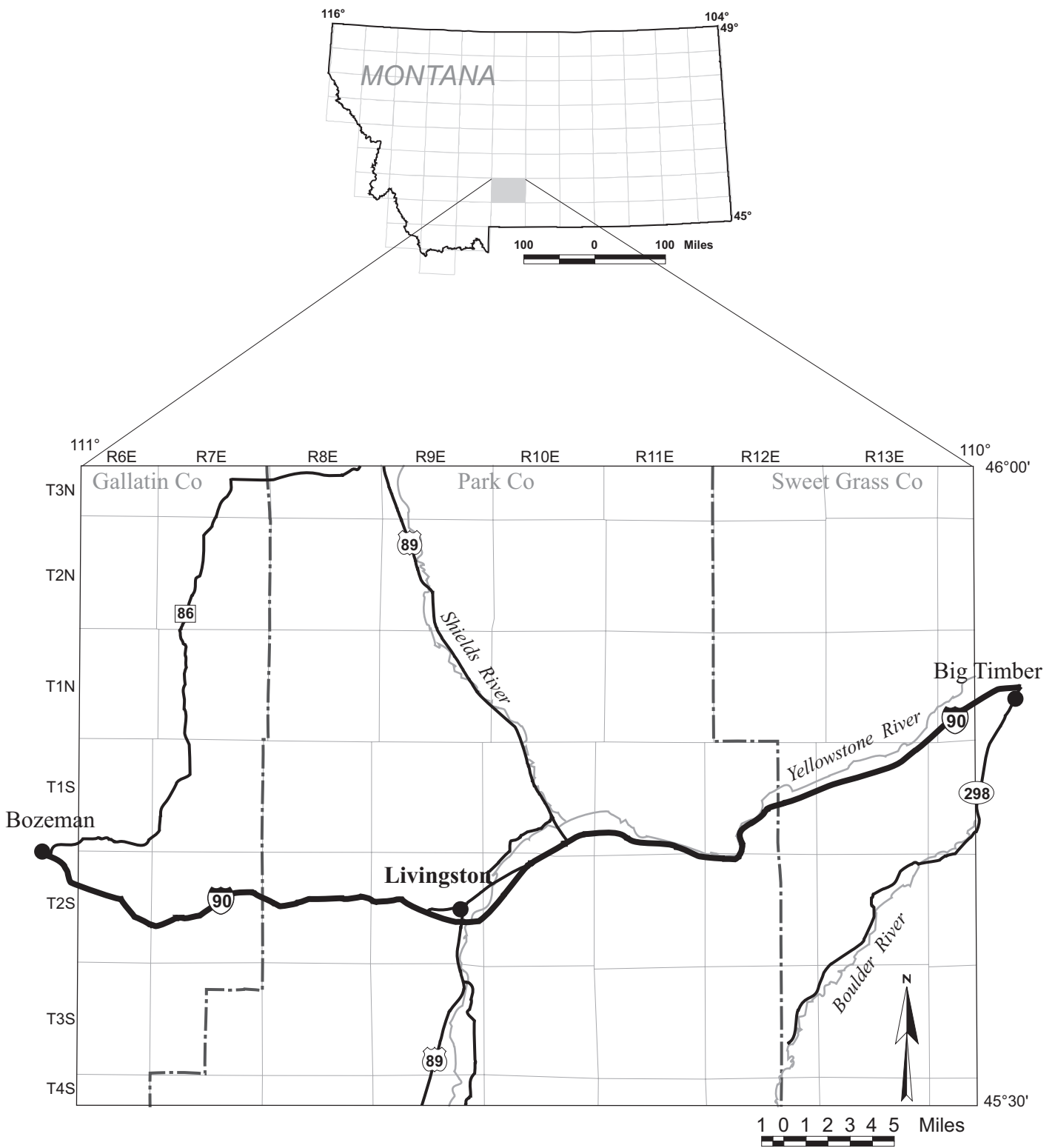


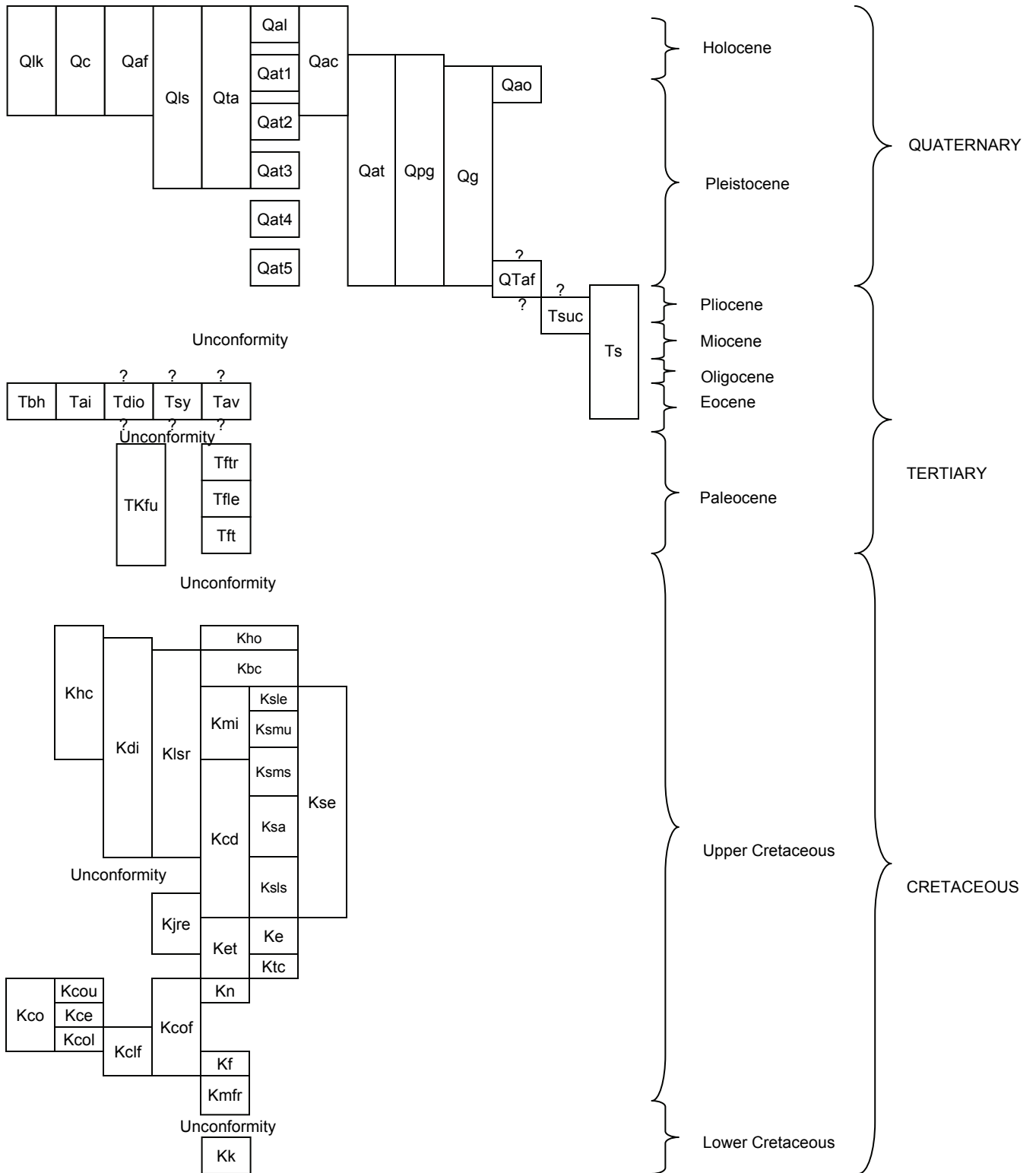
Figure 1. Location map of the Livingston 1:100,000 scale quadrangle.

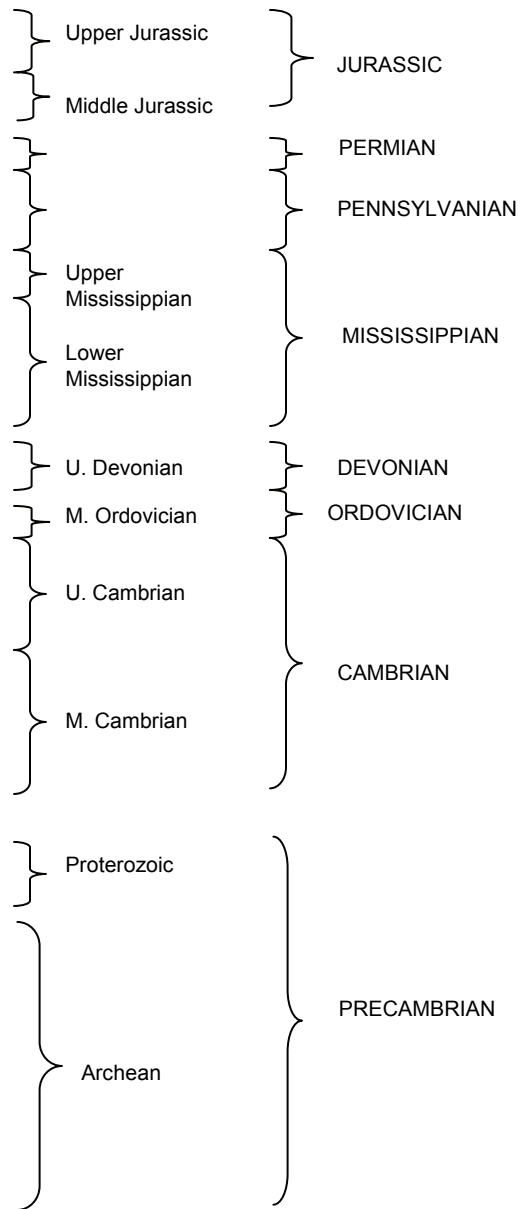
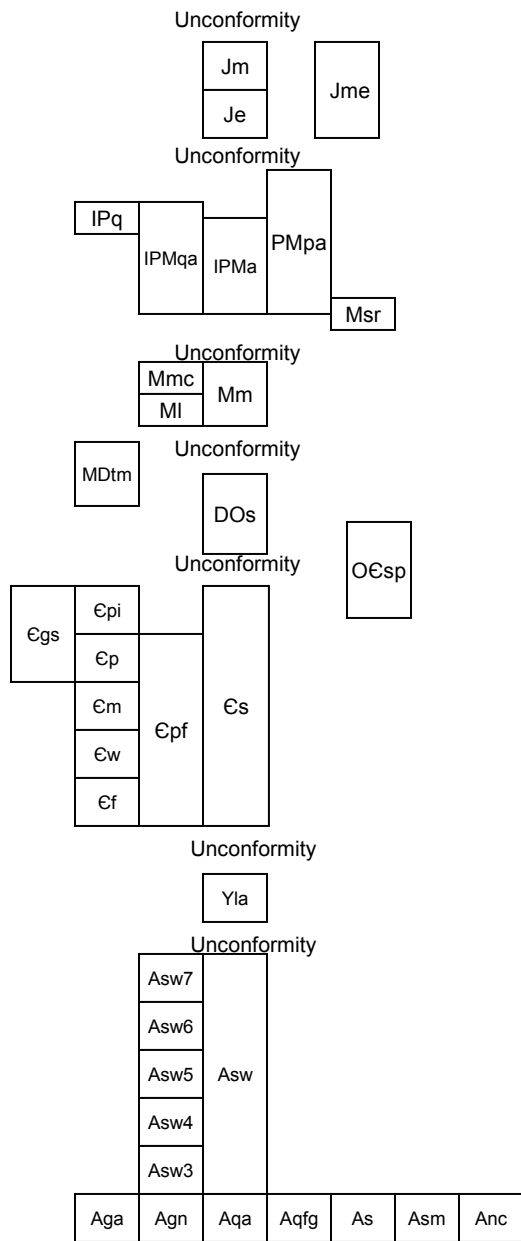
relationship between dikes and sills be determined. In both instances the dikes had intruded the sills.

The structural geology of the western part of the area is well described by David Lageson in Skipp and others (1999). Structural features along the southern edge of the quadrangle are dominated by the Laramide Beartooth uplift and the Nye-Bowler Fault Zone. The Nye-Bowler Fault Zone appears to have controlled the emplacement of several diorite plutons and also has influenced the development of folds and faults along the Beartooth Uplift.

One structural feature in the area is described here because it may have economic importance. A back thrust along the East Boulder River (East Boulder Fault of Garbarini, 1957), has formed an overturned fold verging to the south on the upper plate of the fault (see cross-section A-A'-A"). The core of the fold is made up of highly fractured and sheared rocks of the Stillwater Complex. They appear to have been derived from various gabbros, norites, and possibly anorthosites and can best be described as tectonites. Shear surfaces parallel to the underlying thrust fault are visible in outcrop. The overturned fold in these brittle rocks must have developed by displacement along closely spaced shear surfaces. These rocks have previously been identified as green schist by Garbarini (1957) and as granitic gneiss (Agn) by Van Gosen and others (2000). The identification of Stillwater Complex rocks may be important in exploration for platinum/palladium mineralization.

CORRELATION OF MAP UNITS - LIVINGSTON QUADRANGLE





DESCRIPTION OF MAP UNITS

- Qal Alluvium (Holocene)**—Gravel, sand, silt, and clay along active channels of rivers, creeks, and tributaries.
- Qc Colluvium (Holocene and Pleistocene)**—Locally derived slope-wash deposits mainly of sand, silt, and clay. Commonly grades into Qal. Locally contains well-rounded cobbles reworked from alluvial terrace gravel. Typically thin veneer concealing bedrock, but locally as thick as 30 ft.
- Qac Alluvium and Colluvium (Holocene and Pleistocene)**—Colluvium and alluvium are combined where mapping is insufficient to differentiate between those deposits that grade into one another.
- Qaf Alluvial fan deposit (Holocene and Pleistocene)**—Gravel, sand, silt, and clay deposited in fans being formed by tributary streams along major valley margins. Displays characteristic fan-shaped map pattern and convex upward profile. Typically grades into Qal. Thickness ranges from very thin at toe to as much as 50 ft at head of fans.
- Qlk Lake deposit (Holocene and Pleistocene)**—Gravel near shore, grading into clay and marl in center. Thickness 1-3 ft (Skipp and others, 1999).
- Qta Rock talus deposit (Holocene and Pleistocene)**—Accumulations of locally derived boulder- to pebble-size angular detritus at heads of drainages on both sides of the crest of the Bridger Range.
- Qls Landslide deposit (Holocene and Pleistocene)**—Unconsolidated mixture of soil and blocks of bedrock transported down steep slopes by mass wasting. Characteristic hummocky surface with concentric swales and ridges near down-slope limits. Common along steep slopes beneath resistant rocks but may have developed wherever steep slope and high moisture content produce unstable conditions.
- Qpg Pediment gravel deposit (Holocene and Pleistocene?)**—Angular and subangular cobble and smaller gravel, sand, and silt derived from local bedrock. Surfaces of deposits are smooth pediments sloping away from the Crazy Mountains and Beartooth Mountains. About 10 to 30 ft thick.
- Qg Glacial deposit, undivided (Holocene and Pleistocene)**—Unsorted mixture of clay to boulder size sediment transported and deposited by alpine glaciers. Has characteristic hummocky surface form. Occurs in valleys near the Beartooth Mountains in the southwest corner of the map area. Clasts are predominantly Archean metamorphic rocks with lesser amounts of quartzite, dolomite, and limestone. Thickness unknown.

ALLUVIAL TERRACE GRAVELS

Qat **Alluvial terrace gravel, undivided (Holocene and Pleistocene)**—Gravel, sand, silt, and clay underlying terraces about 20 to 600 ft above present altitude of modern streams and rivers. Equivalent to one or more of Qat₁ through Qat₅. Thickness 10 to 40 ft.

Note: Mapped terrace gravels Qat₁-Qat₅ along the Yellowstone River near Livingston are from preliminary, unpublished mapping by Todd W. Rayne (written communication, 1995)

Qat1 **Alluvial gravel, terrace level 1 (Holocene and Pleistocene)**—Gravel underlying terraces about 10 to 20 ft above present altitude of rivers. Mostly cobbles and pebbles with minor amounts of sand and silt. Clasts are mainly granitic igneous rocks, granitic gneiss, schist, and quartzite, with much less limestone and sandstone. Ten to 40 ft thick.

Qat2 **Alluvial gravel, terrace level 2 (Pleistocene)**—Gravel underlying terraces about 20 to 40 ft above Qal. Mostly cobbles and pebbles with minor amounts of sand and silt. Clasts are mainly granitic igneous rocks, granitic gneiss, schist, and quartzite, with much less limestone and sandstone. Ten to 40 ft thick.

Qat3 **Alluvial gravel, terrace level 3 (Pleistocene)**—Gravel underlying terraces about 50 to 90 ft above present altitude of rivers. Mostly cobbles and pebbles with minor amounts of sand and silt. Clasts are mainly granitic igneous rocks, granitic gneiss, schist, and quartzite, with much less limestone and sandstone. Ten to 30 ft thick.

Qat4 **Alluvial gravel, terrace level 4 (Pleistocene)**—Gravel underlying terraces about 200 to 300 ft above present altitude of rivers. These terraces locally exhibit a relatively steep gradient toward the Yellowstone River Valley and may actually include several levels of terraces that are difficult to distinguish. Cobble- and pebble-size clasts are mainly granite, granitic gneiss, schist, and quartzite. Thickness as much as about 20 ft.

Qat5 **Alluvial gravel, terrace level 5 (Pleistocene)**—Gravel underlying terraces about 400 to 600 ft above present altitude of rivers. Occur mainly as small discontinuous erosional remnants. Cobble- and pebble-size clasts are mainly granite, granitic gneiss, schist, and quartzite. Local calcite cement, especially at base. Thickness ranges from a very thin remnant to about 20 ft

Qao **Alluvium, older, undivided (Quaternary)** - Includes gravel deposits at elevations above present active flood plains and some deposits that contain a significant glaciofluvial component.

QTaf **Alluvial fan deposit (Pleistocene and/or Pliocene)**—Light-gray to light-brown gravel, sand, silt, and clay. In general, coarser sediment is dominant near the head of the fan and finer sediment near the margins. Clasts dominantly matrix-supported, and dominantly poorly sorted, although sediment deposited in distributary channels is moderately to well sorted and clast-supported. Larger clasts subrounded to rounded. May be as much as 200 ft. thick.

BEDROCK MAP UNITS

- Ts** **Sedimentary rocks, undivided**—Tan-weathering, poorly exposed silty claystones that contain unaltered volcanic glass.
- Tsuc** **Sediment and sedimentary rock, undivided; dominantly coarse-grained (Miocene and Pliocene?)**—Poorly stratified variously consolidated tuffaceous siltstone, claystone, sandstone, and conglomerate (Roberts, 1964g).
- Tbh** **Basalt, hypabyssal (Eocene?)**—A small intrusive body in Archean metamorphic rocks near the southwestern corner of the quadrangle.
- Tai** **Alkalic intrusive rocks (Eocene)**—Described by Harlan (1986) as typically sodium rich, silica undersaturated, and strongly alkaline (Wilson and Elliott, 1997)
- Tdio** **Diorite dike and sill (Eocene?)**—An olivine-augite-biotite diorite dike; and a composite sill that consists of upper and lower layers of biotite-augite diorite and a middle layer of syenodiorite (Skipp and others, 1999).
- Tsy** **Syenite (Eocene?)**—Sills intruded into the Fort Union Formation that consist mainly of potassium feldspar with abundant biotite, and locally minor pyroxene. The most prominent of these is the sill that forms Sheep Mountain. Both the syenite intrusive and associated resistant hornfels cap this ridge.
- Tav** **Absaroka Volcanics, undivided (Eocene?)**—Applies to areas within the Absaroka-Beartooth Study Area and the southwestern corner of the Livingston quadrangle where formations within the volcanic sequences were not mapped. Largely composed of units in the Absaroka Volcanic Supergroup. Total thickness unknown.

Fort Union Formation

- Tftr** **Tongue River Member (Paleocene)**—Gray to grayish-yellow, fine- to medium-grained, cross-bedded sandstone. Interbedded with brownish-gray carbonaceous shale and siltstone and minor thin coal beds. Sandstone beds are ledge-forming and commonly support growths of pine trees. About 400 ft of this member is present in the northeastern part of the map area, but thickens dramatically westward. The top of this member was not observed in the map area.
- Tfle** **Lebo Member (Paleocene)**—Predominantly dark-gray to olive shale, locally yellowish-gray claystone, thin interbedded sandstones and siltstone, yellowish gray. Typically forms smooth grassy slopes below the Tongue River Member. Pinches out in the northeastern part of map area; thickness 0 to 250 ft.
- Tft** **Tulloch Member, Fort Union Formation (Paleocene)**—Yellowish-gray, fine- to medium-grained, ledge-forming sandstone, cross-bedded in part. Interbedded with gray to greenish-gray claystone, siltstone, and minor carbonaceous shale.

Supports growths of pine trees. About 400-600 ft thick in the eastern part of the map area but thickens westward where it could not be mapped separately.

- TKfu Fort Union Formation, undivided (Paleocene and Upper Cretaceous)**—Cliff-forming massive sandstone, siltstone, mudstone, and lesser amounts of conglomerate. Conglomerate contains clasts of reworked Cretaceous and older rocks; contains fossil spores, plants, wood, freshwater mollusks, and vertebrates (Roberts, 1964d). Thickness increases toward axis of Crazy Mountain Basin and is probably at least 10,000 ft. Skipp and others (1999) show the Fort Union about 8000 ft thick in a cross-section on the west side of the Crazy Mountains. The lower part of the Fort Union formation near Livingston was assigned to the uppermost part of the Late Cretaceous by Roberts (1963, p. B89; 1965, p. B60).
- Khc Hell Creek Formation (Upper Cretaceous)**—Interbedded light-brownish gray, cliff and ledge-forming, fine-grained, thin- to thick-bedded sandstone, and gray, pale greenish gray and pale purple gray mudstones. Sandstone beds support growths of pine trees. Includes basal beds commonly mapped as Lennep Formation that are typical of basal Hell Creek to the east (personal communication, Susan Vuke and Edie Wilde). The Hell Creek and the upper part of the Livingston Group are laterally equivalent and are eastern and western facies respectively. Hell Creek is recognized east of the Shields River north of the Yellowstone River, and east of Springdale south of the Yellowstone River. Total thickness of the formation is about 900 to 1100 ft.
- Kdi Diorite and diorite porphyry (Upper Cretaceous)**—Dark-gray to medium-gray fine-grained diorite and diorite porphyry with phenocrysts of plagioclase, hornblende, pyroxene, and locally biotite. Occurs as stocks, sills, and dikes in the southeastern corner of the quadrangle. Radiometric age is 74-77 Ma (du Bray and Harlan, 1993 and du Bray and others, 1994).
- Klsr Sliderock Mountain formation, informal, of Livingston Group (Upper Cretaceous)**—This unit includes all the volcanic rocks erupted from the Sliderock stratovolcano (du Bray and others, 1994). Mostly andesite breccia (lahars) gray, pale-purple-gray, pale-greenish gray. Andesite in clasts is porphyritic with phenocrysts of chalky plagioclase, hornblende and pyroxene; matrix is similar but lighter in color and slightly finer grained. Very resistant, forming cliffs and very rugged topography especially near the vent zone in the Sliderock Mountain area (on Big Timber quadrangle, Lopez, 2000). In distal areas, as near town of Springdale, clasts are less angular but otherwise similar to breccias elsewhere. The unit contains minor flows of porphyritic andesite and basaltic andesite, with phenocrysts of plagioclase, hornblende and pyroxene. Thickness is at least 1000 ft (du Bray and others, 1994).
- Kho Hoppers Formation of Livingston Group (Upper Cretaceous)**—Andesitic sandstone with interbedded claystone and siltstone; massive cross-bedded yellowish-gray sandstone member at the base (from Roberts, 1964c).
- Kbc Billman Creek Formation of Livingston Group (Upper Cretaceous)**—Olive-gray, brownish-gray, and grayish-red claystone with interbedded sandstone, siltstone, and conglomerate; contains fresh-water mollusks and dinosaur bones (from Roberts, 1964c).

- Kmi Miner Creek Formation of Livingston Group (Upper Cretaceous)**—Andesitic siltstone and sandstone with beds of tuff and bentonite in lower part; contains fossil spores, plants, wood, and dinosaur bones (from Roberts, 1964c).
- Kcd Cokedale Formation of Livingston Group (Upper Cretaceous)**—Andesitic siltstone and sandstone with claystone, tuff, bentonite and coal; lower part carbonaceous with some thin coal beds; sandstone locally conglomeratic; contains fossil spores, plants, wood, dinosaur bones, and fresh-water mollusks (from Roberts, 1964c).
- Kse Sedan Formation (Upper Cretaceous)**—Members shown only for the Sedan 15' quadrangle in northeast quadrant of map. The Sedan Formation is equivalent to the Miner Creek and Cokedale Formations of the Livingston Group. Descriptions for the members of the Sedan Formation from Skipp and others (1999).
- Ksle Lennep Sandstone Member (Upper Cretaceous)**—Ridge-forming, olive-gray, greenish-gray, volcanoclastic sandstone, conglomerate, and minor mudstone and devitrified tuff. Unit contains rare dinosaur bone fragments, freshwater and brackish-water mollusks, and, in northern part of quadrangle, trace fossils of *Ophiomorpha*. Thickness about 350-500 ft.
- Ksmu Mudstone member, informal (Upper Cretaceous)**—Greenish-gray and brownish-gray, volcanoclastic, mudstone, siltstone, sandstone, and minor interbedded conglomerate and altered vitric tuff. Member forms valleys and low barren hills and has a gradational contact with the middle sandstone member. Unit contains freshwater mollusks, wood, and dinosaur bones. Thickness ranges from 900-1,000 ft.
- Ksms Middle sandstone member, informal (Upper Cretaceous)**—Olive-green, olive-gray, and dark-greenish-gray, volcanoclastic sandstone, conglomerate, mudflow conglomerate, and minor siltstone and mudstone. Unit forms series of ridges and disconformably overlies ash-flow tuff member; basal contact is placed at top of highest ash-flow tuff or ash-flow tuff conglomerate. Thickness is about 1,000-1,430 ft.
- Ksa Ash-flow tuff member, informal (Upper Cretaceous)**—Pale-yellowish-green, light-greenish-gray, grayish-red, and pale-yellowish-brown, welded to nonwelded tuff and ash-flow tuff conglomerate, interbedded with volcanoclastic conglomerate, sandstone, mudstone, and porcelanite. Unit forms resistant knobs and ridges and disconformably overlies lower sandstone member. Thickness about 200-500 ft.
- Ksls Lower sandstone member, informal (Upper Cretaceous)**—Dark-olive-gray, greenish-gray, and yellowish-gray, volcanoclastic sandstone, siltstone, mudstone, altered crystal lithic tuff, minor volcanoclastic granule and pebble conglomerate, minor grayish-red-purple hornblende dacite, and minor lignitic coal. Unit forms a low ridge and has an abrupt contact with underlying Eagle Sandstone throughout most of the Sedan quadrangle. Thickness 500-1,000 ft.
- Kjre Judith River Formation through Eagle Sandstone, undivided (Upper Cretaceous)**—Interbedded gray sandstone, mudstone, and shale. Sandstone is feldspathic and lithic.

Used in southeast part of map area where this thick interval lies between the Telegraph Creek Formation and Hell Creek Formations. Not divided because the intervening Claggett Shale was not observed, although Richards (1957) believed rocks equivalent to the Claggett Shale are present in this area. Thickness is about 1,000 to 1,400 ft.

- Ke Eagle Formation (Upper Cretaceous)**—Light-brownish-gray to very-pale orange, very fine to fine-grained, cross-bedded sandstone, burrowed to bioturbated in part; interbedded with shale. Thickness about 150 ft.
- Ket Eagle Sandstone and Telegraph Creek Formations, undivided (Upper Cretaceous)**
- Ktc Telegraph Creek Formation (Upper Cretaceous)**—Shale and sandy shale, brownish-gray to medium-dark-gray with thin interbedded sandstone. Dusky-red concretions common near base. Sandstone beds thicker and more abundant upward, grading into Eagle Sandstone. Maximum thickness about 250 ft.
- Kn Niobrara Formation (Upper Cretaceous)**—Shale, olive-gray and dark-brownish gray, fissile, and contains abundant thin bentonite beds. Upper half calcareous, containing few very thin bentonite beds, and near top contains thin beds of very calcareous laminated sandstone, siltstone, and sandy limestone. Concretions medium-light-gray to pale-yellowish-brown and from a few inches to one or two ft in diameter are commonly present. *Inoceramus* prisms common. Upper contact placed at change from calcareous shales to non-calcareous shales of Telegraph Creek. Zone of dusky-red concretions in the Telegraph Creek, just above contact also helps establish its position. Basal contact not exposed, thickness unknown.
- Kco Cody Shale (Upper Cretaceous)**—Gray shale and mudstone interbedded with grayish-green and olive-gray sandstone and siltstone and minor brown-weathering nodular limestone and yellowish-gray bentonite. Entire formation is locally fossiliferous and contains fish scales, starfish, ammonites and other mollusks. Thickness is about 1000 ft (Skipp and others, 1999). Division of Cody Shale into members as listed below for the southwestern part of the Livingston quadrangle from Roberts (1965).
- Kcou Upper shale member, informal, of Cody Shale (Upper Cretaceous)**—Dark-gray to brown marine shale and siltstone with interbedded very fine-grained sandstone. Thickness 500 to 845 ft (Roberts, 1965, p. B59).
- Kce Eldridge Creek Member of Cody Shale (Upper Cretaceous)**—Persistent thin-bedded, marine, glauconitic, greenish-gray, fine-grained sandstone. Thickness 90 to 120 ft (Roberts, 1965, p. B59).
- Kcol Lower shale member, informal, of Cody Shale**—Dark-gray to dark-brown marine shale with interbedded siltstone.
- Kclf Lower shale member, informal, of Cody Shale and Frontier Formation, undivided (Upper Cretaceous)**
- Kcf Cody Shale and Frontier Formation, undivided (Upper Cretaceous)**

- Kf Frontier Formation (Upper Cretaceous)**—Light brownish gray, fine-grained thick-bedded to massive, salt and pepper sandstone. Contains three sandstone intervals interbedded with dark-gray, fissile shale. Maximum mapped thickness about 550 ft.
- Kmfr Mowry Shale through Fall River Sandstone, undivided (Upper and Lower Cretaceous)**—This unit is equivalent to Mowry Shale and Thermopolis Shale undivided as mapped by Roberts (1964c). Top of unit (Mowry) is interbedded, siliceous, very fine- to fine-grained sandstone, siltstone, and shale. Contains several prominent bentonite beds. Sandstones and siltstones mostly light gray to medium gray, with a silvery sheen. Fish scales on bedding planes of sandstones and siltstones are characteristic of this formation. Thermopolis Shale is predominantly dark-gray fissile shale, bentonitic shale, and several beds of bentonite. Has hematitic concretionary zone near base. Fall River Sandstone is brownish-gray, thin-bedded, argillaceous, fine-grained, quartz sandstone. Generally poorly exposed in map area, mostly covered by glacial deposits. Total thickness is approximately 1,300 ft.
- Kk Kootenai Formation (Lower Cretaceous)**—Mostly reddish-brown, olive-gray, and dusky-purple mudstone with interbedded, lenticular, fine- to coarse-grained sandstones. Locally thick, lenticular, fluvial, fine-grained sandstone, the Greybull Sandstone, is present at the top. The basal Pryor Conglomerate Member is brown conglomerate and pebbly coarse-grained sandstone and is 20 to 60 ft thick. The total thickness of the Kootenai Formation is about 500 ft
- Jme Morrison Formation and Ellis Group, undivided (Middle and Upper Jurassic)**— Total thickness about 900 ft.
- Jm Morrison Formation (Upper Jurassic)**—Mainly variegated greenish-gray and pale-reddish-brown mudstone. Very fine- to fine-grained, quartzose, calcareous, cross-bedded sandstones are commonly present at about mid-section, 5 to 10 ft thick but locally can be as much as 30 ft thick. Fossil dinosaur remains common. Upper contact placed at the base of the Pryor Conglomerate. The basal contact is placed at the top of fossiliferous limy sandstone and coquina of the underlying Swift Formation. Thickness about 300 ft
- Je Ellis Group, undivided (Middle and Upper Jurassic)**—Includes the Swift, Rierdon, and Piper Formations. The Swift is interbedded medium-gray shale, limestone and limy sandstone, fossiliferous. Brownish-gray, fossiliferous, very sandy limestone occurs at the top of the formation, which generally includes brownish-gray coquina at the top. The Rierdon Formation is mostly pale greenish-gray very fossiliferous shale with minor interbedded brownish gray limestone. Typically poorly exposed, forming smooth slopes littered with fossils, including oysters (*Gryphaea and Ostrea*), belemnites (*Pachyteuthis*), and crinoid fragments (*Pentacrinus*). The Piper is interbedded medium-gray, and pale reddish-gray, thin-bedded limestone and medium-gray shale. Includes thin interbedded gypsum. Forms ledge below smooth slopes of the Rierdon shale. Thickness of the Ellis Group is about 600 ft
- PMpa Phosphoria through Amsden Formations, undivided (Permian, Pennsylvanian, and Upper Mississippian)**—Formations not mapped separately because of narrow outcrop width. Phosphoria is poorly exposed and includes, yellowish-gray shale, light-gray limestone, sandstone and quartzite, commonly grayish-pink, cherty; thickness is 50 to 75

ft. The Phosphoria interval is present in the southeast part of the map area. It thins westward and was not recognized by Richards (1957) or Roberts (1964). The Tensleep Sandstone is light-brown to very pale-orange sandstone, fine-grained, well sorted, well rounded, cross-bedded. Locally contains thin limestone beds, locally cherty near the top, and is locally silicified to form quartzite; about 250 ft thick. The Amsden Formation is interbedded grayish-pink to light-red mudstone, limestone, and siltstone. Limestones are commonly cherty. Unconformably overlies karst surface developed on limestone of the Madison Group. Characteristically produces pink stain on underlying cliffs of Madison Group; thickness about 200 ft but locally tectonically thinned to only a few feet along the mountain front. Total thickness about 500 to 600 ft.

IPMqa Quadrant and Amsden Formations, undivided (Pennsylvanian and Mississippian)—Used in areas where Phosphoria is absent and Quadrant and Amsden outcrop bands are too narrow to map separately.

IPq Quadrant Formation (Pennsylvanian) Quartzite, well sorted quartzose sandstone, and dolomite (Roberts, 1964f).

IPMa Amsden Formation (Pennsylvanian and Mississippian)—Dolomite, calcareous sandstone, and siltstone in upper part; argillaceous limestone in middle part; massive sandstone and red calcareous siltstone and limestone in lower part; mostly concealed (Roberts, 1964b).

Msr Snowcrest Range Group (Upper Mississippian)—Gray and gray-brown limestone and dolostone; red, pink and yellow-orange sandstone; red and pink siltstone; red to purple shale; and red-stained breccia (Skipp and others, 1999).

Mm Madison Group, undivided (Mississippian)—Limestone and dolomitic limestone, light-gray to light-brownish-gray. Thick bedded to massive in the upper part (Mission Canyon Limestone) and thin-bedded to thick-bedded in the lower part (Lodgepole Limestone). Also contains thin interbedded gray shales. Fossiliferous and cherty beds are present throughout. Thickness of the Madison Group is about 1,000 ft in the southeastern part of the map area.

Mmc Mission Canyon Limestone of the Madison Group (Mississippian)—Pale-yellow-brown, massive, poorly bedded limestone and dolostone that weather light-gray and form cliffs and castellated ridges. Unit has a gradational lower contact with Lodgepole Limestone. Thickness is about 720 to 950 ft (Skipp and others, 1999).

MI Lodgepole Limestone of the Madison Group (Mississippian)—Gray and brown limestone and minor dark-brown to black silty shale. Formation unconformably overlies Sappington Member of the Three Forks Formation. Total thickness is 750 to 800 ft (Skipp and others, 1999).

MDtm Three Forks Formation, Jefferson Dolomite, and Maywood Formation, undivided (Mississippian and Devonian)—Light- and dark-brown dolostone; gray and gray-green, nodular limestone; yellowish-brown sandstone; pink and gray siltstone; black and green shale; and minor dolostone breccia. Unit disconformably overlies upper Cambrian beds. This entire interval is 740 to 940 ft thick. (Skipp and others, 1999).

- DOs Sedimentary rocks, undivided (Upper Devonian and Ordovician)**—Includes Three Forks and Jefferson Formations, and Bighorn Dolomite. The Three Forks is mainly yellowish-weathering argillaceous limestone and medium-gray shale, very poorly exposed. The Jefferson Formation is dolomitic limestone, light-brownish-gray, fetid, poorly exposed, typically occurs as float. The Bighorn Dolomite is cliff-forming dolomite and dolomitic limestone, very light gray to very pale orange; lower part massive, thin- to thick-bedded in upper part. Has characteristic pock-marked surface because of differential weathering. Interval thickness about 600 ft.
- OCsp Snowy Range and Pilgrim Limestone, undivided (Lower Ordovician and Upper Cambrian)**—Dark- and light-gray mottled and grayish-brown limestone, limestone-pebble conglomerate, and grayish-green shale. Entire interval about 530 to 700 ft thick (Skipp and others, 1999).
- Es Cambrian sedimentary rocks, undivided (Middle and Upper Cambrian)**—Light red sandstone and quartzite, greenish-gray shale and sandy shale, gray thin-bedded limestone and greenish-gray flat-pebble limestone conglomerate. Includes the Flathead, Wolsey, Meagher, Park, and Pilgrim formations. Thickness is 600 to 800 ft.
- Egs Grove Creek and Snowy Range Formations, undivided (Upper Cambrian)**—Grove Creek Formation is limestone, intraformational conglomerate, and shale; Snowy Range Formation is green shale and gray limestone that is partly a flat-pebble conglomerate; bed of columnar fractured limestone locally present in lower part of Snowy Range Formation; mostly concealed.(Roberts, 1964b). Note: Skipp and others (1999) assigned a Lower Ordovician age to the Snowy Range Formation in the Sedan 15' quadrangle.
- Epi Pilgrim Limestone (Upper Cambrian)**—Massive, cliff-forming, oolitic, mottled, magnesian and dolomitic limestone with edgewise intraformational limestone-pebble conglomerates, interbedded shale and siltstone, and glauconitic limestone. Thickness is 360-430 ft (Skipp and others, 1999 and Roberts, 1964b).
- Epf Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Quartzite undivided (Upper and Middle Cambrian).**
- Ep Park Shale (Upper Cambrian)**—Multicolored shale with thin beds of argillaceous limestone, siltstone, and sandstone; mostly concealed (Roberts, 1964b).
- Em Meagher Limestone (Middle Cambrian)**—Thin-bedded, silty, medium-gray limestone and yellowish-gray dolomite; locally oolitic (Roberts, 1964b).
- EW Wolsey Shale (Middle Cambrian)**—Greenish-gray calcareous shale and mudstone with thin beds of limestone; mostly concealed (Roberts, 1964b).
- Ef Flathead Quartzite (Middle Cambrian)**—Gray to red quartzose sandstone and quartzite; conglomeratic in lower part locally. (Roberts, 1964b).
- Yla La Hood Formation of Belt Supergroup (Proterozoic)**—Dark-grayish green, reddish-weathering, coarse-grained, massive, poorly bedded arkose and conglomeratic arkose. Thickness ranges from 7,000 to 10,000 ft (Skipp and others, 1999).

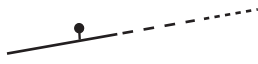
- Asw** **Stillwater Complex, undivided (Archean)**—Layered ultramafic and mafic rocks from peridotites and pyroxenites at the base (ultramafic series) to gabbros and anorthosite in the upper part (banded series). Unit is used in the Long Mountain area where rocks are actually tectonites: mafic rocks are highly sheared, fractured, and altered in upper plate of thrust fault that follows the east-west-trending part of the East Boulder River. Total exposed thickness in Beartooth Mountains is about 22,000 ft.
- Asw7** **Upper Mixed, Upper Gabbro, and Upper Anorthosite Zones (Archean)**
- Asw6** **Middle Anorthosite Zone (Archean)**
- Asw5** **Lower Mixed, Middle Gabbro, and Middle Mixed Zones (Archean)**
- Asw4** **Lower Anorthosite Zone (Archean)**
- Asw3** **Norite and Lower Gabbro Zones (Archean)**
- Aga** **Amphibolite and gneiss (Archean)**—Includes trondhjemitic gneiss-amphibolite, paragneiss, and heterogeneous gneiss sequences of trondhjemitic gneiss, tonalitic gneiss and amphibolite. Also includes minor schist, quartzite, and iron formation (Van Gosen and others, 2000)
- Agn** **Gneissic rocks (Archean)**—Predominantly granitic gneiss and migmatite; commonly consists of alternating bands of more felsic and more mafic gneiss; contains inclusions of metasedimentary rocks (granitic gneiss of Van Gosen and others, 2000).
- Aqa** **Quartzite and amphibolite (Archean)**—Interlayered quartzite and amphibolite. Amphibolite typically contains 60 percent hornblende, 30 percent feldspar, 5 percent garnet, and 5 percent quartz. The abundance of garnet distinguishes this amphibolite from the hornblende-rich gneiss in the quartzofeldspathic gneiss. Quartzite is coarse-grained and locally contains minor garnet, feldspar, anthophyllite, biotite, fuchsite, and sillimanite. A few layers of chlorite schist occur in this unit.
- Aqfg** **Quartzofeldspathic gneiss (Archean)**—Gneiss that consists mainly of feldspars and quartz with variable amounts of hornblende and biotite. Ranges from gray to pink gneiss because of abundant orthoclase. Layers and small concordant bodies of amphibolite occur scattered throughout this gneiss.
- As** **Biotite schist (Archean)**—Biotite schist that includes minor quartzite, iron formation and amphibolite (Van Gosen and others, 1993).
- Asm** **Sillimanite- garnet-biotite gneiss and marble (Archean)**—Gneiss composed of sillimanite, garnet, quartz, feldspar, and biotite. Contains distinctive twinned, white plagioclase porphyroblasts. Coarse-grained marble that contains both calcite and dolomite with minor biotite and magnetite(?) forms layers up to 100 ft thick.
- Anc** **Nappe core complex (Archean)**—Includes Barney Creek amphibolite, George Lake marble, and Jewel quartzite of Van Gosen and others (2000). Includes amphibolite, dolomitic marble and marble, quartzite, minor schist, and iron formation (Van Gosen, and

others, 1993). Exposed south of Livingston in the northwestern part of the Beartooth Mountains.

MAP SYMBOLS



Contact — Dashed where approximately located, dotted where concealed.



Fault — Dashed where approximately located, dotted where concealed. Bar and ball on down-thrown side or sense of movement shown with D and U.



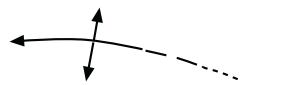
Thrust fault — Sawteeth on upper plate. Dashed where approximately located, dotted where concealed.



Strike slip fault — Direction of relative movement shown.



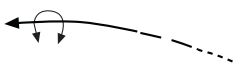
Detachment — Semicircles indicate upper plate, dashed where approximately located, dotted where concealed.



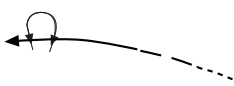
Anticline — Showing trace of axial plane and direction of plunge, dashed where approximately located, dotted where concealed.



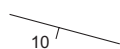
Syncline — Showing trace of axial plane and direction of plunge, dashed where approximately located, dotted where concealed.



Overturned anticline — Showing trace of axial plane and direction of plunge, dashed where approximately located, dotted where concealed.



Overturned syncline — Showing trace of axial plane and direction of plunge, dashed where approximately located, dotted where concealed.



Strike and dip of beds



Strike and dip of overturned beds



Horizontal beds



Vertical beds



Dike — Shown in red on map



Sill — Shown in red on map

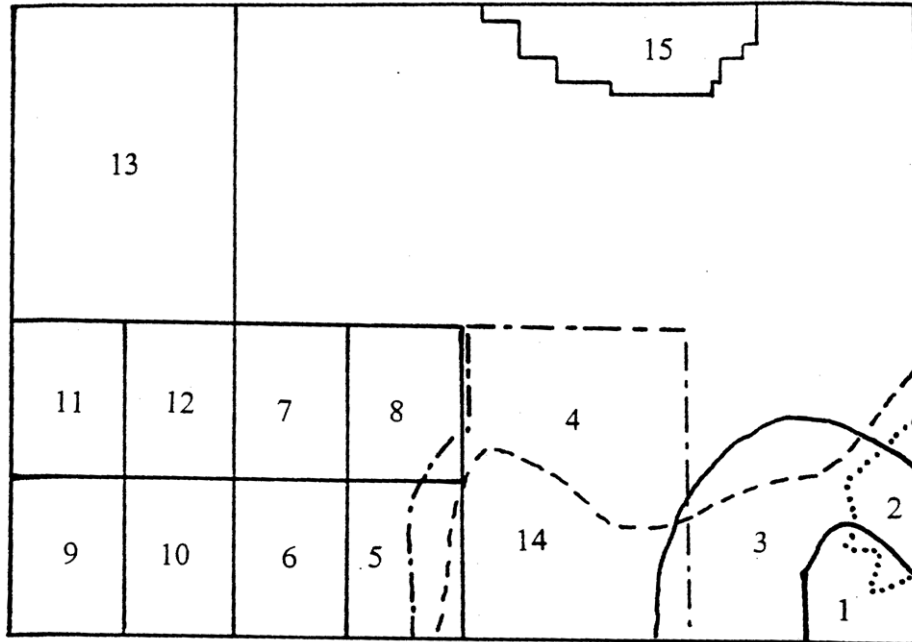


Calcite vein — Shown in red on map.



Hornfels

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8. Roberts, A.E., 1964d, Geology of the Livingston quadrangle, Montana: U.S. Geological Survey Map GQ-259, scale 1:24,000.
9. Roberts, A.E., 1964e, Geologic map of the Mystic Lake quadrangle, Montana: U.S. Geological Survey Miscellaneous Geological Investigations Map I-398, scale 1:24,000. Note: This quadrangle has been renamed Mount Ellis.

10. Roberts, A.E., 1964f, Geologic map of the Maxey Ridge quadrangle, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-396, scale 1:24,000. Note: This quadrangle has been renamed Bald Knob.
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