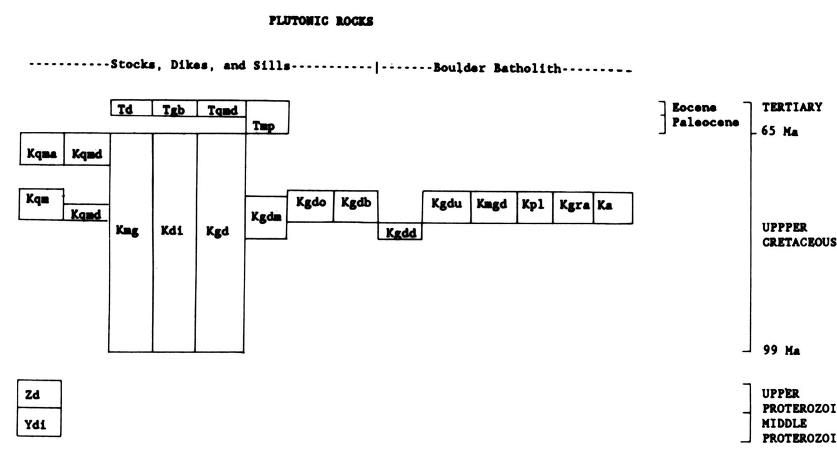
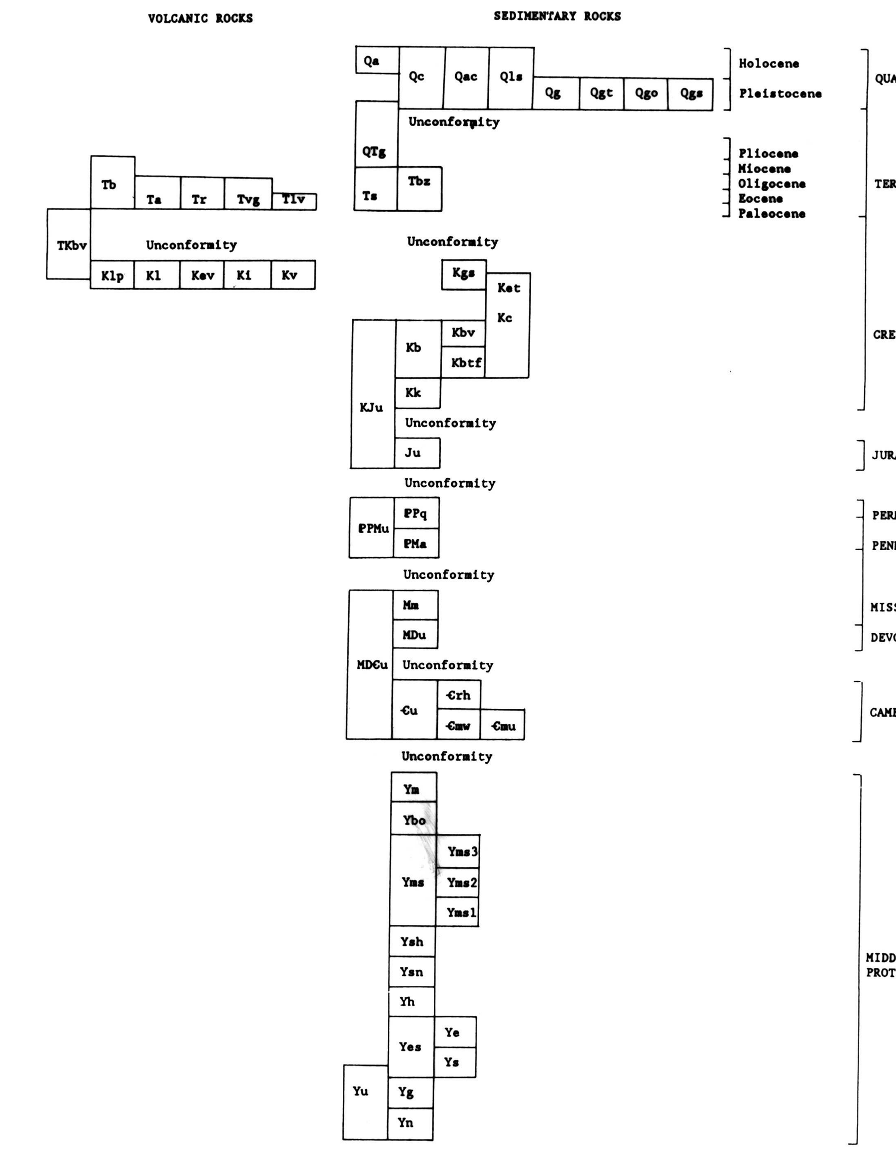




Contact

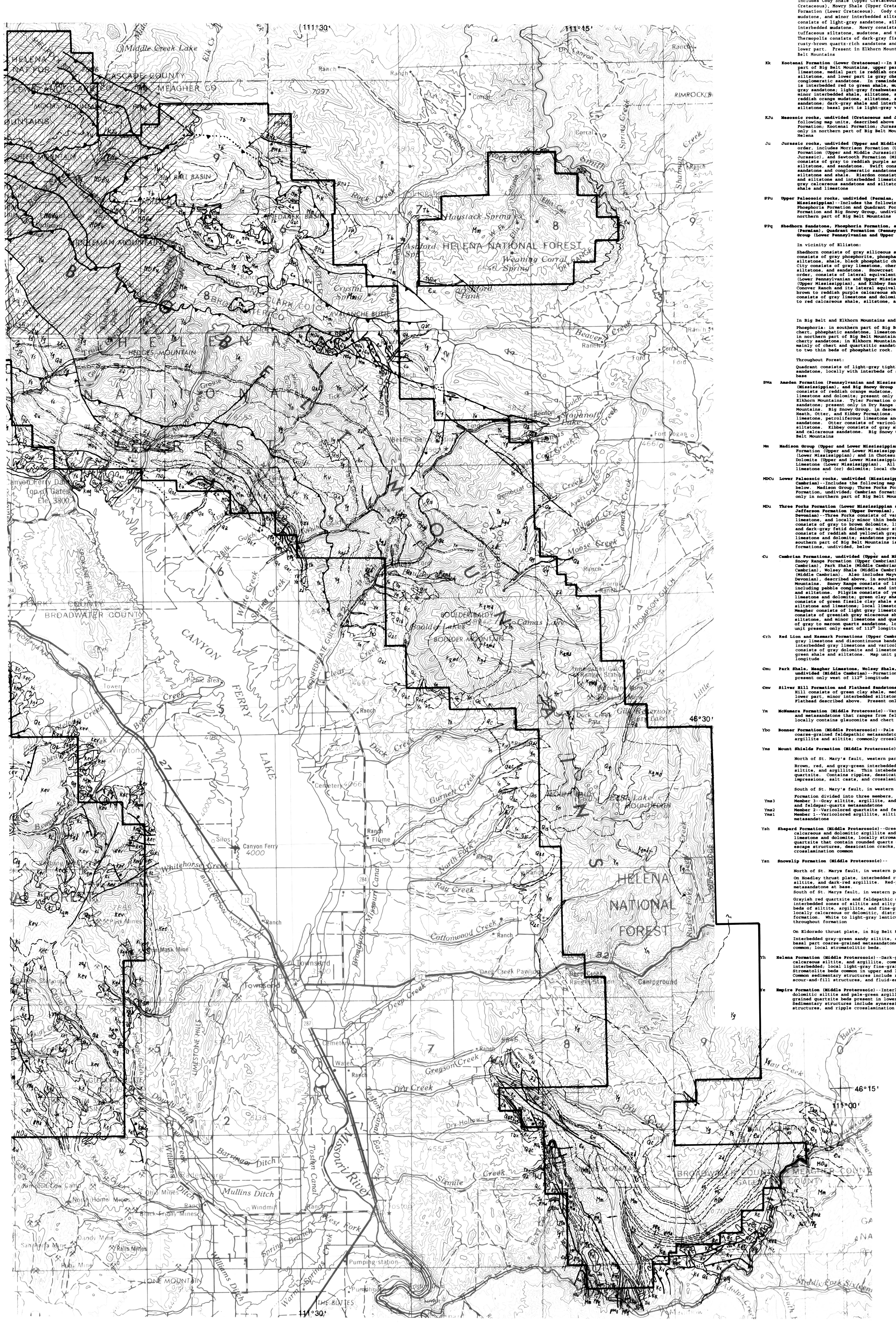
Normal fault--dotted where concealed. Bar-and-ball on downthrown side

Thrust fault--dotted where concealed. Teeth on upper plate

Anticline--showing approximate trace of axial surface and direction of plunge

Syncline--showing approximate trace of axial surface and direction of plunge

Area where several formations are combined into compound map units



DESCRIPTION OF MAP UNITS

The description of map units is from data in the map publications in the "References Cited" list below; C.A. Wallace (unpub. data) for most of the rock units in the Butte 1° x 2° quadrangle of the western part of the Forest; references cited in Chapter B of this report on the Helena National Forest; and Schieber (1985) for the Newland Formation.

SEDIMENTARY ROCKS

Qa **Alluvium (Quaternary)**--Unconsolidated silt, sand, and gravel along modern-day streams

Qc **Colluvium (Quaternary)**--Unconsolidated deposits consisting mainly of slope wash and talus

Qac **Alluvium and colluvium, undivided (Quaternary)**--Unconsolidated mantle of alluvium, colluvium, and, near Lake Helena, wind-blown silt

Qls **Landslide deposits (Quaternary)**--Unconsolidated earthflow deposits that contain a mixture of rock materials ranging from silt to boulders in size

Qg **Glacial deposits, undivided (Quaternary)**--Glacial till, moraine, glaciofluvial deposits, and minor alluvium and colluvium

Qgt **Glacial till (Quaternary)**--Unconsolidated deposits of unsorted and unstratified clay, silt, sand, gravel, and boulders; in general lacks morainal form

Qgo **Glacial outwash deposits (Quaternary)**--Unconsolidated clay, silt, sand, and gravel deposited from meltwater streams that flowed from glaciers; generally stratified

Qgs **Glacial-lake deposits (Quaternary)**--Sand, silt, and clay that is sorted, stratified, and firmly compacted. Present in vicinity of Missouri River

QTg **Conglomerate (Quaternary or Tertiary)**--Unconsolidated gravel and fan deposits, and conglomerate in northern part of Big Belt Mountains

Ts **Stream and lake deposits, undivided (Tertiary)**--Sandstone, siltstone, claystone, shale, marl, siliceous sinter, and minor poorly sorted conglomerate; locally carbonaceous and tuffaceous; rare coal and limestone. Volcaniclastic components common

Tbz **Bozeman Group, undivided (Tertiary)**--In southeasternmost part of Big Belt Mountains, interbedded siltstone and tuff. Along central and southwesternmost flank of Big Belt Mountains, composed of tuffaceous conglomerate and sandstone, subordinate stream-laid siltstone, freshwater limestone, and volcanic ash

Kgs **Golden Spike Formation (Upper Cretaceous)**--Sandstone and conglomerate that includes both volcanoclastic and non-volcaniclastic units; and lava flows and flow breccias. Present only in westernmost part of Forest

Ket Slim Sam Formation, Eagle Sandstone, and Telegraph Creek Formation (Upper Cretaceous)--Slim Sam Formation lies at top of sequence and is composed of interbedded volcaniclastic sandstone, tuff, and lapilli tuff; present only in Elkhorn Mountains. Eagle Sandstone consists of ledge-forming chert-rich sandstone; in Elkhorn Mountains locally contains fossil marine placers of magnetite. Telegraph Creek Formation consists of marine mudstone, siltstone, and sandstone

Kb Blackleaf Formation, undivided (Upper and Lower Cretaceous)--In descending order, includes Vaughn, Taft Hill, and Flood Members, described below

Kbv Vaughn Member (Upper Cretaceous)--Upper part is dark siliceous sandstone and interbedded siliceous shale and siltstone; light gray porcellanite and lapilli tuff. Middle part is lenticular conglomerate of quartzite and chert clasts in matrix of sandstone. Lower part is sandstone interbedded with shale, bentonitic mudstone, and siltstone; some interbeds of limestone and limestone concretions. Present in western part of Forest

Kbtf Taft Hill and Flood Members (Lower Cretaceous)--Taft Hill consists of sandstone and dark shale, mudstone, and siltstone. Flood consists of sandstone in upper part and dark gray fissile shale and minor interbedded siltstone in lower part. Present in western part of Forest

Kc Colorado Group (Upper and Lower Cretaceous)--In descending order, includes Cody Shale (Upper Cretaceous), Frontier Formation (Upper Cretaceous), Mowry Shale (Upper Cretaceous), and Thermopolis Formation (Lower Cretaceous). Cody consists of dark gray mudstone, and minor interbedded siltstone and sandstone. Frontier consists of light-gray sandstone, siltstone, and lesser interbedded mudstone. Mowry consists of sandstone, siltstone, tuffaceous siltstone, mudstone, and tuffaceous mudstone. Thermopolis consists of dark-gray fissile shale in upper part and rusty-brown quartz-rich sandstone and interbedded siltstone in lower part. Present in Elkhorn Mountains and southern part of Big Belt Mountains

Kk **Kootenai Formation (Lower Cretaceous)**--In Elkhorn Mountains and southern part of Big Belt Mountains, upper part is light-gray freshwater limestone, medial part is reddish orange mudstone and interbedded siltstone, and lower part is gray chert-rich sandstone and conglomeratic sandstone. In remainder of Forest, uppermost part is interbedded red to green shale, mudstone, siltstone, and light-gray sandstone; light-gray freshwater limestone and dolomite, and minor interbedded shale, siltstone, and sandstone; medial part is reddish orange mudstone, siltstone, shale, and light-gray sandstone; dark-gray shale and interbedded sandstone and siltstone; basal part is light-gray vitreous quartzite

KJu **Mesozoic rocks, undivided (Cretaceous and Jurassic)**--Includes the following map units, described above and below. Blackleaf Formation; Kootenai Formation; Jurassic rocks, undivided. Present only in northern part of Big Belt Mountains and directly west of Helena

Ju **Jurassic rocks, undivided (Upper and Middle Jurassic)**--In descending order, includes Morrison Formation (Upper Jurassic), Swift Formation (Upper and Middle Jurassic), Rierdon Formation (Middle Jurassic), and Sawtooth Formation (Middle Jurassic). Morrison consists of gray to reddish purple and orange mudstone, shale, siltstone, and sandstone. Swift consists of gray calcareous sandstone and conglomeratic sandstone, and minor interbeds of siltstone and shale. Rierdon consists of gray calcareous shale and siltstone and interbedded limestone. Sawtooth consists of gray calcareous sandstone and siltstone, and lesser amounts of shale and limestone

PPu **Upper Paleozoic rocks, undivided (Permian, Pennsylvanian, and Mississippian)**--Includes the following map units, described below. Phosphoria Formation and Quadrant Formation, undivided; Amsden Formation and Big Snowy Group, undivided. Present only in northern part of Big Belt Mountains

PPq **Shedhorn Sandstone, Phosphoria Formation, and Park City Formation (Permian), Quadrant Formation (Pennsylvanian), and Snowcrest Range Group (Lower Pennsylvanian and Upper Mississippian), undivided**--

In vicinity of Elliston:

Shedhorn consists of gray siliceous sandstone. Phosphoria consists of gray phosphorite, phosphatic and calcareous sandstone, siltstone, shale, black phosphatic chert, and limestone. Park City consists of gray limestone, cherty limestone, calcareous siltstone, and sandstone. Snowcrest Range Group, in descending order, consists of lateral equivalents of Conover Ranch Formation (Lower Pennsylvanian and Upper Mississippian), Lombard Limestone (Upper Mississippian), and Kibbey Sandstone (Upper Mississippian). Conover Ranch and its lateral equivalents consist of reddish brown to reddish purple calcareous shale and siltstone. Lombard consists of gray limestone and dolomite. Kibbey consists of gray to red calcareous shale, siltstone, and sandstone.

In Big Belt and Elkhorn Mountains and near Helena:

Phosphoria: in southern part of Big Belt Mountains, consists of chert, phosphatic sandstone, limestone, and quartzose sandstone; in northern part of Big Belt Mountains, consists of chert and cherty sandstone; in Elkhorn Mountains and near Helena, consists mainly of chert and quartzitic sandstone, but locally contains one to two thin beds of phosphatic rock.

Throughout Forest:

Quadrant consists of light-gray tightly cemented quartz-rich sandstone, locally with interbeds of siltstone and dolomite at base

PMa **Amsden Formation (Pennsylvanian and Mississippian), Tyler Formation (Mississippian), and Big Snowy Group (Upper Mississippian)**--Amsden consists of reddish orange mudstone, shale, sandstone, and gray limestone and dolomite; present only in Big Belt Mountains and Elkhorn Mountains. Tyler Formation consists of pale brown sandstone; present only in Dry Range area, northeast of Big Belt Mountains. Big Snowy Group, in descending order, comprised of Heath, Otter, and Kibbey Formations. Heath consists of gray limestone, petroliferous limestone and shale, and calcareous sandstone. Otter consists of varicolored shale, limestone, and siltstone. Kibbey consists of gray shale, siltstone, limestone, and calcareous sandstone. Big Snowy Group present only in Big Belt Mountains

Mm **Madison Group (Upper and Lower Mississippian)**--Includes Mission Canyon Formation (Upper and Lower Mississippian) and Lodgepole Formation (Lower Mississippian); and in Choteau quadrangle, Castle Reef Dolomite (Upper and Lower Mississippian) and Allan Mountain Limestone (Lower Mississippian). All units are composed of limestone and (or) dolomite; local chert

MDЄu **Lower Paleozoic rocks, undivided (Mississippian, Devonian, and Cambrian)**--Includes the following map units, described above and below. Madison Group; Three Forks Formation and Jefferson Formation, undivided; Cambrian formations, undivided. Present only in northern part of Big Belt Mountains

MDu **Three Forks Formation (Lower Mississippian and Upper Devonian), Jefferson Formation (Upper Devonian), and Maywood Formation (Lower Devonian)**--Three Forks consists of varicolored shale, siltstone, limestone, and locally minor thin beds of sandstone. Jefferson consists of gray to brown dolomite, limestone, limestone breccia, and dark-gray fetid dolomite; minor siltstone and shale. Maywood consists of reddish and yellowish gray siltstone and interbedded limestone and dolomite; sandstone present locally. Maywood in southern part of Big Belt Mountains is included with Cambrian formations, undivided, below

Єu **Cambrian Formations, undivided (Upper and Middle Cambrian)**--Includes Snowy Range Formation (Upper Cambrian), Pilgrim Limestone (Upper Cambrian), Park Shale (Middle Cambrian), Meagher Limestone (Middle Cambrian), Wolsey Shale (Middle Cambrian), and Flathead Sandstone (Middle Cambrian). Also includes Maywood Formation (Lower Devonian), described above, in southern part of Big Belt Mountains. Snowy Range consists of limestone and dolomite, including pebble conglomerate, and intervals of micaceous shale and siltstone. Pilgrim consists of yellowish gray to brown limestone and dolomite; green clay shale in lower part. Park consists of green fissile clay shale and minor interbeds of siltstone and limestone; local limestone pebble conglomerate. Meagher consists of light gray limestone and dolomite. Wolsey consists of greenish gray micaceous shale and glauconitic siltstone, and minor limestone and quartzite. Flathead consists of gray to maroon quartz sandstone, locally conglomeratic. Map unit present only east of 112° longitude

Єrh **Red Lion and Hasmark Formations (Upper Cambrian)**--Red Lion consists of gray limestone and discontinuous bands of siliceous dolomite, and interbedded gray limestone and varicolored shale. Hasmark consists of gray dolomite and limestone, minor local interbeds of green shale and siltstone. Map unit present only west of 112° longitude

Єmu **Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone, undivided (Middle Cambrian)**--Formations described above. Map unit present only west of 112° longitude

Єmw **Silver Hill Formation and Flathead Sandstone (Middle Cambrian)**--Silver Hill consists of green clay shale, medium-gray limestone, and, in lower part, minor interbedded siltstone, sandstone, and shale. Flathead described above. Present only in vicinity of Elliston

Ym **McNamara Formation (Middle Proterozoic)**--Varicolored argillite, siltite, and metasandstone that ranges from feldspathic to quartz-rich; locally contains glauconite and chert

Ybo **Bonner Formation (Middle Proterozoic)**--Pale pink to light brown fine- to coarse-grained feldspathic metasandstone; sparse dark-red argillite and siltite; commonly crosslaminated, local ripples

Yms **Mount Shields Formation (Middle Proterozoic)**--

North of St. Mary's fault, western part of Forest:

Brown, red, and gray-green interbedded feldspathic metasandstone, siltite, and argillite. Thin intebeds of pale-green to light-gray quartzite. Contains ripples, dessication cracks, raindrop impressions, salt casts, and crosslaminated beds.

South of St. Mary's fault, in western part of Forest:

Formation divided into three members, in descending order:

Yms3 Member 3--Gray siltite, argillite, and quartz-rich metasandstone and feldspar-quartz metasandstone

Yms2 Member 2--Varicolored quartzite and feldspar-quartz metasandstone

Yms1 Member 1--Varicolored argillite, siltite, feldspathic metasandstone

Ysh **Shepard Formation (Middle Proterozoic)**--Green, white, and yellowish-gray calcareous and dolomitic argillite and siltite; argillaceous limestone and dolomite, locally stromatolitic; local beds of quartzite that contain rounded quartz grains. Ripples, fluid-escape structures, dessication cracks, mudchip rip-up clasts, and crosslamination common

Ysn **Snowslip Formation (Middle Proterozoic)**--

North of St. Marys fault, in western part of Forest:

On Hoadley thrust plate, interbedded red-brown siltite, gray-green siltite, and dark-red argillite. Red-purple feldspathic metasandstone at base.

South of St. Marys fault, in western part of Forest:

Grayish red quartzite and feldspathic metasandstone, and interbedded zones of siltite and silty argillite. Zones of green beds of siltite, argillite, and fine-grained metasandstone, locally calcareous or dolomitic, distributed unevenly through formation. White to light-gray lenticular quartzite distributed throughout formation

On Eldorado thrust plate, in Big Belt Mountains:

Interbedded gray-green sandy siltite, dark-green argillite, and in basal part coarse-grained metasandstone. Ripple and rip-up clasts common; local stromatolitic beds.

Yh **Helena Formation (Middle Proterozoic)**--Dark-gray dolomitic limestone, calcareous siltite, and argillite, commonly cyclically interbedded; local light-gray fine-grained metasandstone. Stromatolite beds common in upper and lower parts of formation. Common sedimentary structures include ripples, syneresis cracks, scour-and-fill structures, and fluid-escape structures

Ye **Empire Formation (Middle Proterozoic)**--Interlaminated gray-green dolomitic siltite and pale-green argillite. Light-gray fine-grained quartzite beds present in lower part of formation. Sedimentary structures include syneresis cracks, water-expulsion structures, and ripple crosslamination

Ys **Spokane Formation (Middle Proterozoic)**--Interbedded grayish red purple argillite and siltite, and lesser gray-green siltite; middle part, and to lesser extent lower part, contains light-gray feldspathic metasandstone. Local dolomitic limestone. Common sedimentary structures include load casts, rip-up clasts, fluid-escape structures, ball-and-pillow structures, syneresis cracks, and ripple crosslamination

Yes **Empire and Spokane Formations, undivided (Middle Proterozoic)**-- Units described above

Yu **Lower Belt Supergroup, undivided (Middle Proterozoic)**--Includes the Spokane, Greyson, and Newland Formations, described above and below. Present only in northern part of Big Belt Mountains

Yg **Greyson Formation (Middle Proterozoic)**--

In northwestern part of Forest:

Interbedded dark greenish gray siltite and argillite, a few beds of lenticular quartzose metasandstone, and dolomitic siltite that contains algal laminations.

In Big Belt Mountains:

Upper member consists chiefly of argillite in lower part that grades upward into siltite; local gray fine-grained feldspathic metasandstone. Minor limestone and calcareous siltite and metasandstone present in upper part. Lower member consists of interbedded gray fine- to coarse-grained feldspathic metasandstone and, locally, quartzite; some beds ripple crosslaminated; conglomeratic beds, locally graded from small boulders in lower part to pebbles in upper part; medium-gray feldspathic siltite; local yellowish brown finely laminated (porcellanitic?) siltite; and gray finely laminated argillite

Yn **Newland Formation (Middle Proterozoic)**--Upper member consists of interbedded units of medium-gray limestone, some beds mottled dark gray with algal-like structures; calcareous and noncalcareous finely laminated siltite, and locally ripple crosslaminated siltite; locally light-gray, yellowish-orange-weathering porcellanitic argillite; minor feldspathic metasandstone and, locally, quartzite. Lower member consists of medium-gray, light-brown-weathering argillite and dolomitic argillite that is finely laminated. Minor interbeds of gray fine-to medium-grained feldspathic metasandstone beds a few inches thick. Formation exposed only in Big Belt Mountains

VOLCANIC ROCKS

Tb **Basalt (Tertiary)**--Basalt flows, flow breccia, and plugs

Ta **Andesite (Tertiary)**--Andesite flows, flow breccia, and plugs

Tr **Rhyolite (Tertiary)**--Flows, porphyry plugs, breccia plugs, dikes, tuff, and welded tuff; includes minor andesite and latite flows and plugs

Tvg **Volcanic rocks, undivided (Tertiary)**--Volcanic flows and dikes of basaltic, andesitic, and latitic composition; present only west of 112° longitude

Tlv **Lowland Creek Volcanics (Eocene)**--Volcanic rocks ranging from rhyolite to quartz latite to dacite in composition; includes plugs, dikes, stock, diatreme, flows, welded tuff, and air-fall tuff, locally volcaniclastic rocks. Present in Elkhorn Mountains and to west, south of U.S. Highway 12

TKbv **Basaltic and andesitic volcanic rocks (Paleocene or Late Cretaceous)**--Lava flows, breccia, plugs, tuff, and volcaniclastic sedimentary rocks. Present only in southwesternmost part of Forest, south of Elliston

Klp **Lamprophyre (Cretaceous?)**--Dark gray dike of highly altered igneous rock composed chiefly of mafic minerals; present along west flank of middle part of Big Belt Mountains

Kl **Quartz latite (Cretaceous?)**--Light gray intrusions of porphyritic latite to quartz latite. Present along west flank of central part of Big Belt Mountains

Kev **Elkhorn Mountains Volcanics, undivided (Late Cretaceous)**--Medium to dark gray lava flows, flow-breccia, air-fall tuff, and ash-flow tuff; composition ranges from rhyolitic to andesitic, and locally basaltic. Unit also includes related intrusive rocks (described below) where they are areally too small to show separately at this scale. Volcaniclastic sedimentary rocks, derived from debris of volcanic rocks, include conglomerate, sandstone, and mudstone. Present only in Elkhorn Mountains and area to west

Ki **Intrusive rocks related to Elkhorn Mountains Volcanics, undivided (Late Cretaceous)**--Dacite to andesite sills, dikes, and irregularly shaped intrusions. Shown only in Elkhorn Mountains

Kv **Volcanic and volcaniclastic rocks, undivided (Late Cretaceous)**--Welded tuff and lava flows ranging from rhyolite to dacite in composition; dikes of andesitic composition; and volcaniclastic conglomerate, sandstone, siltstone, and mudstone. Unit present only in central and southern part of Big Belt Mountains

PLUTONIC ROCKS

Td **Dacite (Eocene)**--Porphyritic dacite plug of Knopf (1963). Present northwest of Helena

Tgb **Gabbro (Tertiary)**--Dark-gray gabbro pluton. Present only east of Elliston

Tqmd **Quartz monzodiorite (Early Tertiary)**--Gray granitic intrusion of monzodiorite composition. Present only southeast of Lincoln

Tmp **Monzonite porphyry (Eocene and Paleocene)**--Light-gray monzonite in stocks, dikes, and sills; present only in northwesternmost part of Forest

Kqma **Aegerine-augite quartz monzonite (Late Cretaceous)**--Light-gray aegerine-augite-bearing granitic intrusions of monzodiorite composition. Present only in Boulder Baldy-Boulder Mountains area of Big Belt Mountains

Kqmd **Quartz monzodiorite (Late Cretaceous)**--Light-gray quartz monzodiorite intrusions. Present only in Big Belt Mountains

Kqm **Quartz monzonite and granite (Late Cretaceous)**--Light- to medium-gray quartz monzonite intrusion. Present only in eastern part of Elkhorn Mountains

Kmg **Monzogranite and monzonite porphyry (Cretaceous)**--Light-gray monzogranitic intrusion. Present only south of Lincoln

Kdi **Diorite and diorite porphyry (Late(?) Cretaceous)**--Dark-gray dioritic rocks that form small stocks, dikes, and sills. Present in area between Helena and Elliston in western part of Forest

Kgd **Granodiorite and related rocks (Late Cretaceous)**--Medium-gray granodiorite stocks and plugs

Kgdm **Granodiorite of Marysville stock (Late Cretaceous)**--Medium-gray granodiorite stock near Marysville, northwest of Helena

Kgdo **Granodiorite of Ogden Mountain stock (Late Cretaceous)**--Medium-gray granodiorite stock near Ogden Mountain, southwest of Lincoln

Kgdb **Granodiorite of Blackfoot City (Late Cretaceous)**--Medium-gray intrusion granodiorite stock near Blackfoot City, northwest of Elliston

Kgdd **Granodiorite of Dalton Mountain stock (Late Cretaceous)**--Medium-gray granodiorite stock near Dalton Mountain, south of Lincoln

Kgdu **Unionville granodiorite of Knopf (1963) (Late Cretaceous)**--Dark-gray granodiorite pluton along the northern margin of the Boulder batholith. Present south of Helena and in northwestern part of Elkhorn Mountains

Kmgd **Butte quartz monzonite (Late Cretaceous)**--Light- to medium-gray granitic intrusions with many separate phases; composition ranges from monzogranite to granodiorite. Includes small areas of aplite (described below) too small to show separately. Forms the major rock type of the Boulder batholith in Elkhorn Mountains and in area south of U.S. Highway 12

Kpl **Priest Pass leucomonzonite of Knopf (1963) (Late Cretaceous)**--Light-gray, small leucomonzonite plutonic masses; present only west of Helena, north of U.S. Highway 12

Kgra **Graphophyre of Knopf (1963) (Late Cretaceous)**--Dark-gray monzogabbro of plagioclase and clinopyroxene phenocrysts in groundmass of micropegmatite; present only south of Helena along northern margin of the Boulder batholith

Ka **Aplite, alaskite, and pegmatite (Late Cretaceous)**--Light-gray to white rock of feldspar and quartz. Forms sheets, pods, dikes, and irregularly shaped masses within Butte quartz monzonite. Only larger bodies are shown. Present only in Elkhorn Mountains and in area south of U.S. Highway 12

Zd **Diorite, gabbro, and microgabbro (Late Proterozoic)**--Dark-gray to gray-green sills and dikes

Ydi **Andesite, basaltic andesite, and dacite (Middle Proterozoic)**--Dark gray-green mafic sills; present only in northwestern part of Forest

GEOLOGIC MAPPING

The geologic map is at a scale of 1:126,720 (1 in. equals 2 mi), in accord with the scale of the Forest Use Map of the Helena National Forest. At the beginning of this project, no geologic map was available that covered the entire Helena National Forest with the appropriate scale or geologic detail for the mineral resource assessment.

For the entire western part of the Forest, geologic maps were available from CUSMAP (Conterminous U.S. Mineral Resource Assessment Program) studies of the Butte (Wallace and others, 1986) and Choteau (Mudge and others, 1982) 1° x 2° quadrangles (scale of 1:250,000, 1 in. equal about 4 mi) (pl. 1). The geologic base for the area of the Forest within these two quadrangles was compiled by enlarging these geologic maps to 1:126,720.

For the Elkhorn Mountains, all geologic mapping was compiled from the previously published maps of Klepper and others (1957, 1971), Smedes (1966), Knopf (1963), and Greenwood and others (1990). These maps were reduced to 1:126,720 and transferred to the Forest base map.

For the Big Belt Mountains, geology was compiled from several fairly detailed published maps, supplemented locally by reconnaissance mapping conducted for this study by du Bray (1995) and by Tysdal (unpub. reconnaissance mapping) in the central to southern part of the mountains; this geology was reduced to 1:126,720. In the northern part of the Big Belt Mountains, a geologic map of the Gates of the Mountains Wilderness (Reynolds and Close, 1984) was enlarged to 1:126,720.

In the Gates of the Mountains Wilderness and locally north of Lincoln, the geologic map of the Forest contains map units that are comprised of two or more formations. These compound map units abut single-formation map units that characterize the remainder of the Forest, producing an apparent (but nonexistent) fault at the join of the two source maps. The compound map units are indicated by a diagonal-rule pattern on the geologic map.

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