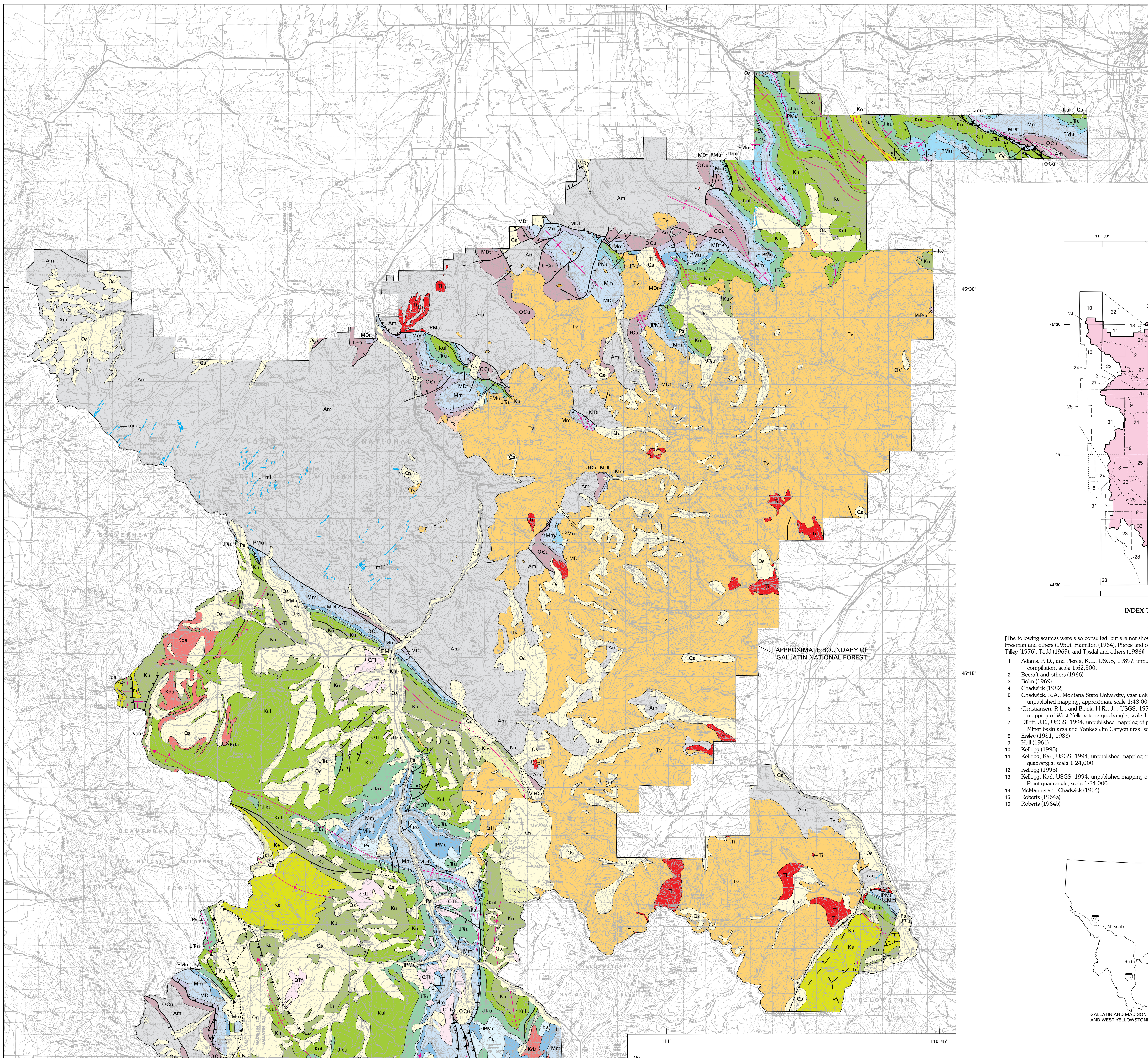
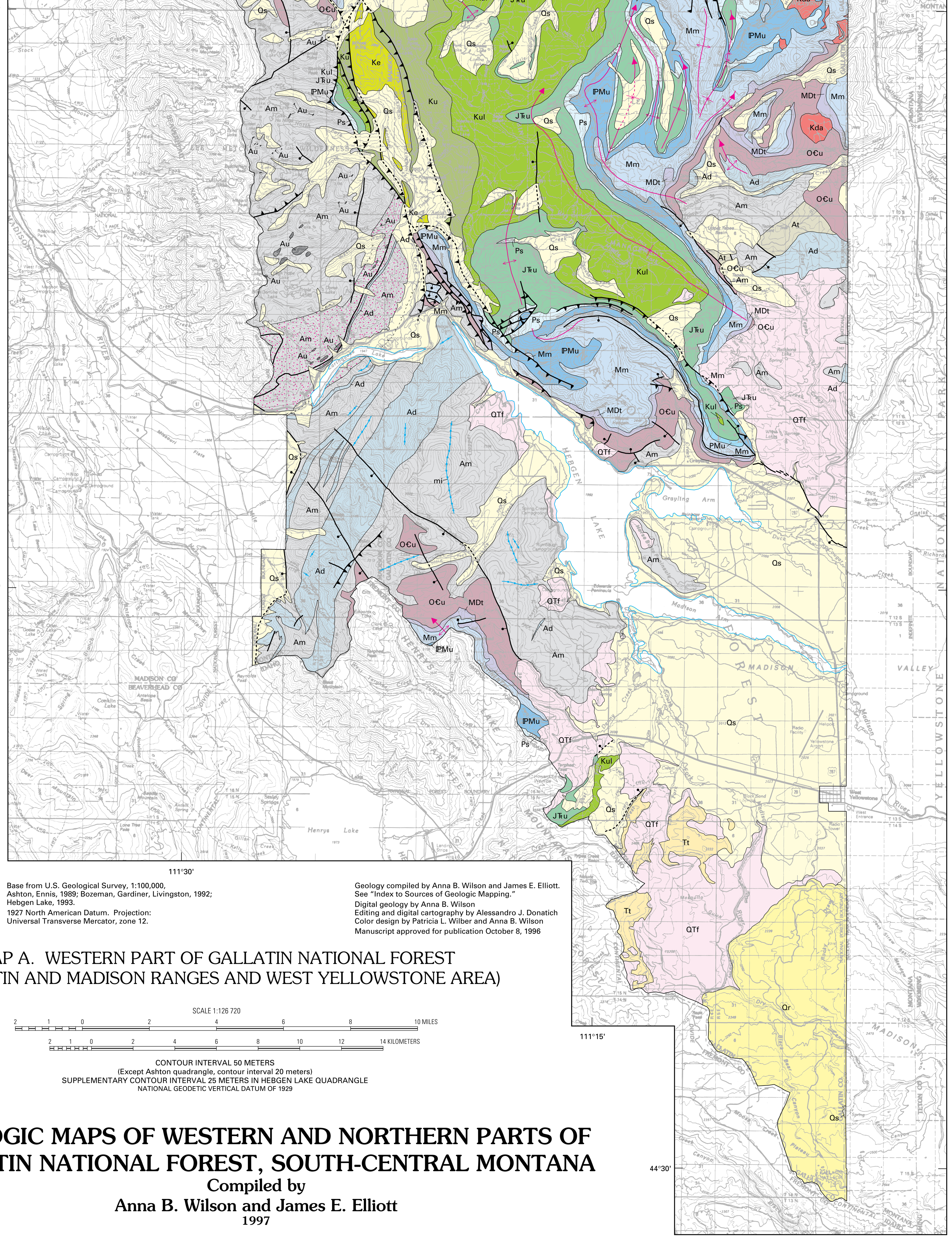




Base from U.S. Geological Survey, 1:100,000,
Ashton, Ennis, 1989; Bozeman, Gardiner, Livingston, 1992;
Hebgen Lake, 1993.
1927 North American Datum. Projection:
Universal Transverse Mercator, zone 12.

Geology compiled by Anna B. Wilson and James E. Elliott.
See "Index to Sources of Geologic Mapping."
Digital geology by Anna B. Wilson
Editing and digital cartography by Alessandro J. Donatich
Color design by Patricia L. Wilber and Anna B. Wilson
Manuscript approved for publication October 8, 1996

MAP A. WESTERN PART OF GALLATIN NATIONAL FOREST (GALLATIN AND MADISON RANGES AND WEST YELLOWSTONE AREA)

SCALE 1:126 720

2 1 0 2 4 6 8 10 MILES

2 1 0 2 4 6 8 10 12 14 KILOMETERS

CONTOUR INTERVAL 50 METERS
(Except Ashton quadrangle, contour interval 20 meters)
SUPPLEMENTARY CONTOUR INTERVAL 25 METERS IN HEBGEN LAKE QUADRANGLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOLOGIC MAPS OF WESTERN AND NORTHERN PARTS OF GALLATIN NATIONAL FOREST, SOUTH-CENTRAL MONTANA

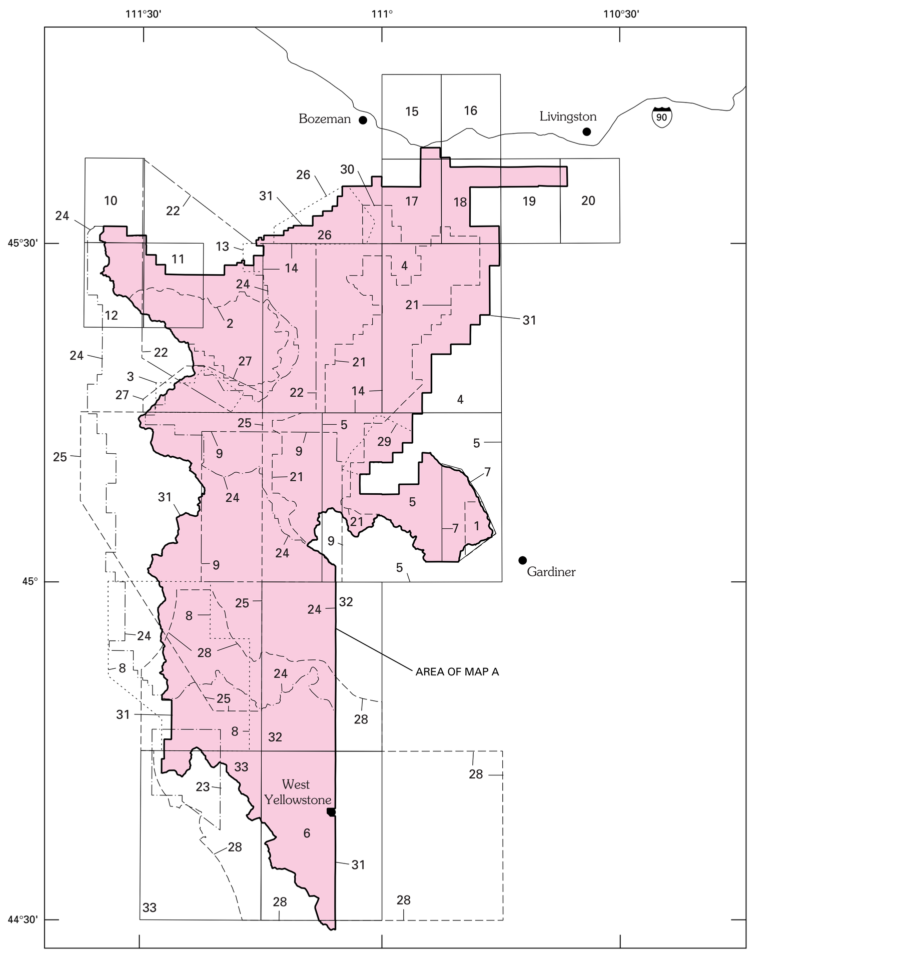
Compiled by
Anna B. Wilson and James E. Elliott
1997

INTRODUCTION

The geology of Gallatin National Forest (GNF) was mapped as part of an evaluation of its mineral resource potential by the U.S. Geological Survey (USGS). Map A, the western part of GNF, south of Interstate Highway 90 (I-90) and west of the Yellowstone River, includes the Gallatin and Madison Ranges and the West Yellowstone area. Map B, the northern part of GNF, north of I-90, includes the Bridger Range and Crazy Mountains. The eastern part of GNF, south of I-90 and east of the Yellowstone River, was examined previously by the USGS as part of the mineral resource potential study of the Absaroka-Beartooth study area and is published separately (Hammarstrom and others, 1993).

The colored maps of this report supersede a black-and-white version (Wilson and Elliott, 1995). Both maps were digitized, compiled, and produced using the USGS software program GSMAP (Selner and Taylor, 1993) and unreleased proprietary updates to it. All original source maps were digitized at their original scales and map projections, then merged into the final digital map formats. After editing, the digital maps were filtered to remove all points not necessary for improving resolution at a scale of 1:126,720 (2 mi per in., the scale used in this report and by the U.S. Forest Service).

Rocks range in age from Archean to Holocene. For purposes of resource assessment (Elliott and others, 1995), many rock units have been combined on these maps. Only brief descriptions of rock units are presented here; the reader is referred to original sources for detailed rock unit descriptions.

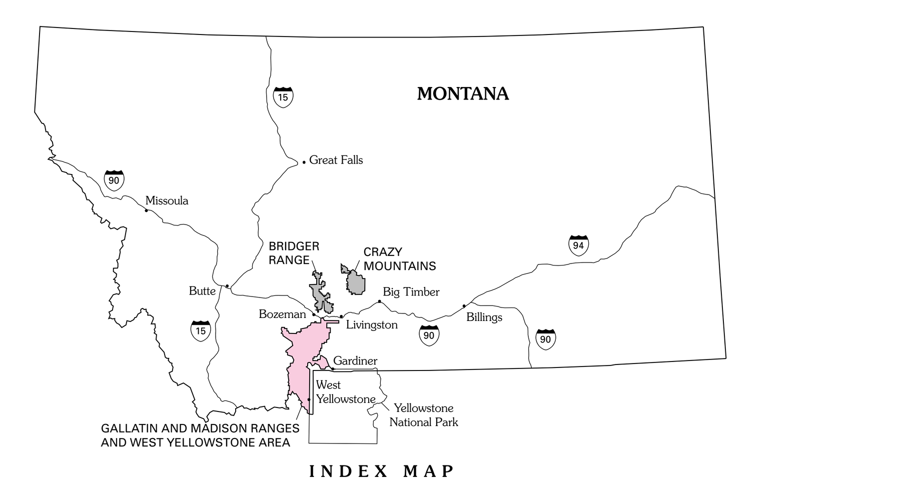


INDEX TO SOURCES OF GEOLOGIC MAPPING

SOURCES OF GEOLOGIC MAPPING

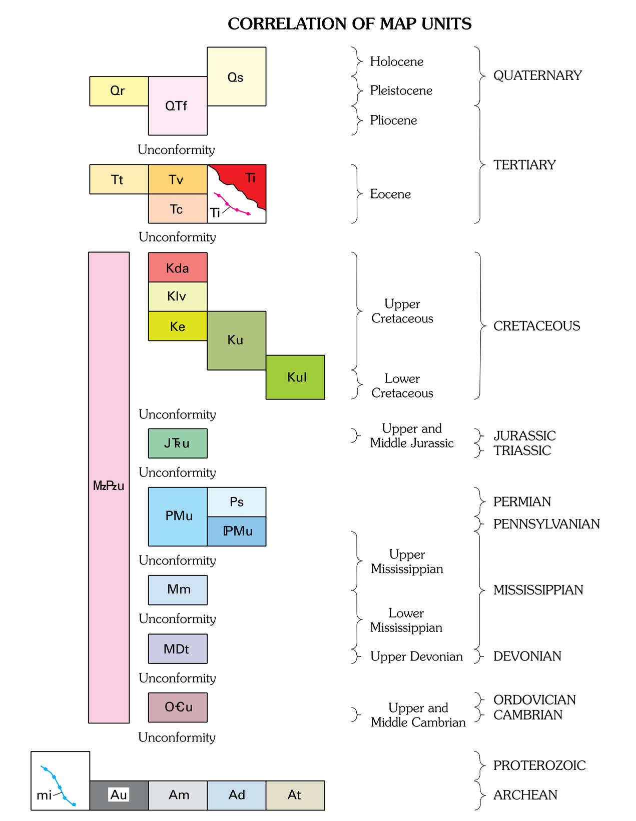
[The following sources were also consulted, but are not shown on the "Index to Sources of Geologic Mapping": Fix (1940), Fraser and others (1969), Freeman and others (1950), Hamilton (1964), Pierce and others (1991), Richards (1957), Roberts (1972), Spencer and Kozak (1975), Swanson (1970), Tilley (1976), Todd (1969), and Tysdal and others (1986)]

1 Adams, K.D., and Pierce, K.L., USGS, 1989?, unpublished map compilation, scale 1:62,500.
2 Becraft and others (1966)
3 Bolm (1969)
4 Chadwick (1982)
5 Chadwick, R.A., Montana State University, year unknown, unpublished mapping, approximate scale 1:48,000.
6 Christiansen, R.L., and Blank, H.R., Jr., USGS, 1975, unpublished mapping of West Yellowstone quadrangle, scale 1:62,500.
7 Elliott, J.E., USGS, 1994, unpublished mapping of part of Tom Miner basin area and Yankee Jim Canyon area, scale 1:24,000.
8 Erslev (1981, 1983)
9 Hall (1961)
10 Kellogg (1995)
11 Kellogg, Karl, USGS, 1994, unpublished mapping of Willow Swamp quadrangle, scale 1:24,000.
12 Kellogg (1993)
13 Kellogg, Karl, USGS, 1994, unpublished mapping of part of Beacon Point quadrangle, scale 1:24,000.
14 McMannis and Chadwick (1964)
15 Roberts (1964a)
16 Roberts (1964b)
17 Roberts (1964c)
18 Roberts (1964d)
19 Roberts (1964e)
20 Roberts (1964f)
21 Simons and others (1985)
22 Spencer and Kozak [1973 (1980)]
23 Sumner (1988)
24 Tysdal and Simons (1985)
25 Tysdal (1990)
26 Tysdal (1966)
27 Tysdal, R.G., USGS, 1980–83, unpublished mapping of Big Sky–Lone Mountain area, scale 1:62,500.
27 Wilson, A.B., Hammarstrom, J.M., Van Gosen, B.S., and Elliott, J.E., USGS, 1993, unpublished mapping of Big Sky–Lone Mountain area, scale 1:24,000.
28 U.S. Geological Survey (1964).
29 Van Gosen, B.S., USGS, 1993, unpublished mapping of part of Tom Miner basin area, scale 1:24,000.
30 Weber (1965)
31 Wilson and Elliott (1995)
32 Witkind (1969)
33 Witkind (1972)



INDEX MAP

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

GALLATIN AND MADISON RANGES AND WEST YELLOWSTONE AREA

Qs **Surficial deposits, undivided (Quaternary)**—Alluvium, colluvium, talus, landslide deposits, rock glaciers, glacial and glaciofluvial deposits, and boulder fields. Only selected major areas, generally exposed for at least 1 mi in a single direction, are shown

Qr **Rhyolite (Pleistocene)**—Rhyolite flows of Madison Plateau, in extreme southern part of map area. Upper part (about 100 ft) is agglomerate consisting of blocks of black obsidian (ranging from granules to large blocks) in a matrix of unconsolidated glass shards. Much of the obsidian is crumbly and spherulitic (1–3 cm in diameter and varicolored). Middle part (several hundred feet) is flow-banded rhyolite. Lower part (30 ft) is perlitic and spherulitic obsidian agglomerate (Hamilton, 1964)

QTf **Felsic volcanic rocks (Pleistocene and Pliocene)**—Includes Plateau Rhyolite [Central Plateau Member (Pleistocene: Christiansen and Blank, 1972)] and Yellowstone Group [including Lava Creek Tuff (Pleistocene: Christiansen and Blank, 1972) and Huckleberry Ridge Tuff (Pliocene: Love, 1989)]. Plateau Rhyolite is light-gray, dense, lithoidal, fine-grained to aphanitic ash-flow tuff. Phenocrysts (1.5 mm in diameter) of quartz, sanidine, pyroxene, fayalite, and sphene form 25 percent of rock (Witkind, 1972). Yellowstone Group is light-brown to gray, thick-bedded, mostly rhyolitic, porphyritic welded tuff and minor flows. Matrix is chiefly devitrified glass shards; phenocrysts of sanidine, quartz, and sparse plagioclase (Tysdal and Simons, 1985; Tysdal, 1990)

Tt **Trachyte, trachybasalt, and basalt (Eocene)**—Basalt porphyry, trachybasalt porphyry, and trachyte porphyry in volcanic flows and breccias; probably correlates with Absaroka Volcanic Supergroup. Mapped south of Hebgen Lake (Christiansen and Blank, 1975)

Tv **Volcanic rocks of the Absaroka Volcanic Supergroup, undivided (Eocene)**—Includes Hyalite Peak and Golmeyer Creek Volcanics (Chadwick, 1982). Volcanic flows and breccia, andesite and basalt flows, pyroxene trachyte porphyry, breccia, tuff, conglomerate, sandstone, channel-fill deposits, and minor carbonaceous siltstone. Lava flows mostly gray, fine-grained to sparsely porphyritic andesite and basalt; plagioclase and pyroxene phenocrysts; aphanitic groundmass; some lava more (Simons and others, 1985; Tysdal and Simons, 1985) or less (McMannis and Chadwick, 1964) silicic. Volcanic breccia interlayered with the flows. Some volcanic units contain abundant fossil wood

Ti **Intrusive rocks, undivided (Eocene)**—Dacitic, andesitic, and basaltic dikes, sills, and small stocks. Dacitic rocks show distinct flow structures and are conspicuously porphyritic; contain phenocrysts of plagioclase, hornblende, and biotite; matrix of feldspar microlites and devitrified glass. Andesitic and basaltic rocks contain a few small phenocrysts of plagioclase in pilotaxitic groundmass of andesine(?) microlites and interstitial pyroxene and opaque minerals (Simons and others, 1985)

Tc **Conglomerate (Eocene)**—Poorly indurated conglomerate of cobbles and boulders of Precambrian gneiss, amphibolite, vein quartz, Paleozoic carbonate strata, and volcanic rocks. Contacts not exposed; presumed to be basal unit of Tertiary sequence. Mapped only near Garnet Mountain in northern part of Gallatin Range (McMannis and Chadwick, 1964)

Kda **Dacitic and andesitic intrusive rocks (Upper Cretaceous)**—Gray porphyritic dacite and, locally, andesite sills and dikes; hornblende and plagioclase phenocrysts; fine-grained to aphanitic plagioclase, potassium feldspar, and quartz matrix. Includes dacite porphyry laccolith, more than 1,500 ft thick, along Gallatin River (Witkind, 1969); sills as much as 400 ft thick and dikes 3–50 ft thick (Tysdal and Simons, 1985; Tysdal, 1990). K-Ar and $^{40}Ar/^{39}Ar$ dates on hornblende 68–69 Ma (Tysdal and others, 1986; Tysdal, 1990)

Klv **Livingston Formation (Upper Cretaceous)**—Upper member is volcaniclastic sandstone, mudflow breccia, volcanic conglomerate, and mudstone; middle member is dacite to basalt, autoclastic breccia, tuff breccia, welded tuff, dacite flows, and volcaniclastic sandstone; lower member is intertonguing volcaniclastic sandstone, olivine basalt, mudflow breccia, volcanic conglomerate, and mudstone. Well exposed. Total thickness 1,500–2,500 ft (Roberts, 1972; Tysdal and Simons, 1985; Tysdal, 1990)

Ke **Eagle Sandstone, Virgelle Sandstone, and Everts Formation, undivided (Upper Cretaceous)**—In extreme northeastern part of map area, near Cokedale, Eagle Sandstone is divided into an unnamed upper member and a lower member, the Virgelle Sandstone. Upper part of upper member includes an upper zone of coal beds, carbonaceous siltstone, and sandstone that is underlain by well-bedded to massive, medium- to well-sorted, light-olive-gray quartzose sandstone and siltstone; lower part of upper member contains two units of coal, carbonaceous siltstone, and fine-grained sandstone. Coal zones contain commercial-grade, high-volatile bituminous coal beds, some of coking quality (Roberts, 1972); some beds were extensively mined until the early 1900's. Underlying Virgelle Sandstone is very light gray, well-cemented, massive to crossbedded, fine-grained arkosic sandstone (Roberts, 1972). Total thickness of Eagle Sandstone is 645 ft, including the 110-ft-thick Virgelle Sandstone (Roberts, 1966).

In Madison Range only the Virgelle Sandstone is mapped and overlying strata are assigned to the Everts Formation rather than the Eagle Sandstone (Tysdal and Simons, 1985; Tysdal, 1990). Upper 1,000–1,200 ft of Everts Formation is gray, fine- to medium-grained quartz-rich sandstone and interbedded siltstone; contains mudstone, porcellanite, and finely crystalline limestone beds; lower 200–300 ft is thin interbeds of mudstone, siltstone, shale, coal, and minor sandstone, and a few beds of several-feet-thick, light-gray, fine- to medium-grained, crossbedded sandstone. Virgelle Sandstone is thin- to thick-bedded, medium- to coarse-grained, crossbedded quartz sandstone that forms prominent white-weathering ledges; thickness 75–165 ft (Tysdal, 1990)

Ku **Upper Cretaceous sedimentary rocks, undivided**—In descending order, includes Eagle Sandstone, Telegraph Creek Formation, Cody Shale, Frontier Formation, and Mowry Shale. Includes Eagle Sandstone (Ke) along northwest corner of Yellowstone National Park; see description of unit Ke. Telegraph Creek Formation is predominantly siltstone and thin-bedded, moderately well sorted sandstone cemented with calcite and containing calcareous concretions; weathers distinctive yellowish gray (Roberts, 1972). In Madison Range, upper part of Telegraph Creek Formation is light-brown-weathering mudstone and siltstone, with minor sandstone and glauconite in some beds; middle part has white-weathering tuffaceous siltstone marker; lower part is siltstone and mudstone overlying ledge-forming, gray, "salt-and-pepper" sandstone (Tysdal and Simons, 1985). About 675 ft thick in Madison Range (Tysdal and Simons, 1985). Cody Shale is mudstone and thin interbeds of gray-green siltstone and minor fine-grained sandstone; about 1,000 ft thick (Tysdal and Simons, 1985). Frontier Formation is gray sandstone interlayered with darker gray siltstone and mudstone in northern part of map area; gray-green glauconitic sandstone, siltstone, and mudstone with zones of coaly shale, pale-green tuff, and porcellanite in southern part; total thickness about 400 ft (Tysdal and Simons, 1985). Mowry Shale is included only along Gallatin River in central part of map area; elsewhere, Mowry Shale is included with undivided Upper and Lower Cretaceous sedimentary rocks (Kul). Upper part of Mowry Shale is slope-forming, gray mudstone; lower part is pastel-colored mudstone, porcellanite, welded tuff, siltstone, and sandstone; total thickness about 700–900 ft (Tysdal and Simons, 1985)

Kul **Upper and Lower Cretaceous sedimentary rocks, undivided**—In descending order, includes Mowry Shale (Upper Cretaceous) and Muddy Sandstone, Thermopolis Shale, and Kootenai Formation (Lower Cretaceous). Includes Mowry Shale except along Gallatin River in central part of map area where Mowry is included with undivided Upper Cretaceous sedimentary rocks unit (Ku); see unit Ku for description of Mowry Shale. Upper part of Muddy Sandstone is gray to tan sandstone and arkosic sandstone; middle part is dark-gray siltstone, fine-grained sandstone, and shale; lower part is poorly sorted, ledge-forming, crossbedded sandstone; total thickness about 125–350 ft (Tysdal and Simons, 1985). Upper part of Thermopolis Shale is dark-gray, locally carbonaceous, fissile shale; lower part is brown, rusty-weathering sandstone with crossbeds and ripple marks; total thickness 200–250 ft (Tysdal and Simons, 1985). Upper part of Kootenai Formation is nonmarine gastropod limestone; middle part is variegated red-yellow-gray mudstone, siltstone, and minor sandstone and limestone; lower part is ledge-forming, cherty, quartzose sandstone and conglomeratic sandstone; total thickness about 350–500 ft (Tysdal and Simons, 1985)

JTRu **Jurassic and Triassic sedimentary rocks, undivided**—In descending order, includes Morrison Formation (Upper Jurassic); Ellis Group (Upper and Middle Jurassic); Chugwater Formation (Triassic); and Thaynes(?) Formation, Woodside Siltstone, and Dinwoody Formation (Lower Triassic). Morrison Formation is varicolored nonmarine claystone and mudstone; about 225–400 ft thick (Simons and others, 1985; Tysdal and Simons, 1985). Ellis Group comprises Swift, Rierdon, and Sawtooth Formations. Swift Formation is cream-colored to brown to gray, oolitic, shelly, cherty, calcareous and glauconitic sandstone, sandy limestone, and chert-pebble conglomerate; Rierdon Formation is gray-brown oolitic limestone, fossiliferous gray shale, and argillaceous limestone; Sawtooth Formation (lithic equivalent to Piper Formation of central Montana) is gray, fine-grained, fossiliferous limestone, argillaceous limestone, shale, and varicolored siltstone. Ellis Group is about 80–300 ft thick (Simons and others, 1985; Tysdal, 1985). Chugwater Formation is poorly exposed red siltstone, shale, and fine-grained sandstone; few thin gypsum beds; about 500 ft thick (Simons and others, 1985). Thaynes(?) Formation is gray-orange, thin-bedded, calcareous siltstone and gray-green clay shale; local ledge former; only 0–10 ft thick (Tysdal and Simons, 1985). Woodside Siltstone is red, thin-bedded siltstone and mudstone interbedded with gypsum and thin gray limestone beds; thickness varies from 0 to 725 ft (Tysdal and Simons, 1985). Dinwoody Formation is brown to yellow-gray, chocolate-brown-weathering, thin-bedded limestone, silty limestone, and calcareous siltstone; about 70–265 ft thick (Simons and others, 1985; Tysdal and Simons, 1985)

Pmu **Permian, Pennsylvanian, and Mississippian sedimentary rocks, undivided**—In descending order, includes Shedhorn Sandstone (Permian), Quadrant Sandstone (Pennsylvanian), and Amsden Formation (Lower Pennsylvanian and Upper Mississippian). Sandstone, siltstone, mudstone, shale, chert, limestone, and dolomite. Refer to units Ps and PMu for descriptions of formations

Ps **Shedhorn Sandstone (Permian)**—Lateral equivalent to the Phosphoria Formation to the west and south (McKelvey and others, 1959). Mostly brown to gray, locally conglomeratic sandstone containing abundant grains, nodules, and layers of chert and pellets of phosphorite (Simons and others, 1985). From top to bottom: interlayered chert beds and common vertical cylindrical burrows; dark-colored, gray to brown, thin-bedded chert with siltstone partings over phosphatic mudstone and limestone; brown to dark-gray, well-cemented sandstone with interbeds of chert and limestone; and yellow-gray dolomite with abundant chert fragments and a few interbeds of dark-brown sandstone. Thickness 115–225 ft (Tysdal and Simons, 1985; Tysdal, 1990)

PMu **Quadrant Sandstone (Pennsylvanian) and Amsden Formation (Lower Pennsylvanian and Upper Mississippian), undivided**—Quadrant Sandstone is white to tan, bedded, clean, well-sorted quartz sandstone with silica or calcite cement. Interbeds of yellow-brown dolomite and gray limestone in lower part. Thickness about 200–315 ft (Tysdal, 1990). Underlying Amsden Formation is red to pink, calcareous siltstone to shale. Upper part of formation contains calcareous sandstone cemented with iron oxides; middle and lower parts contain limestone, limestone-pebble conglomerate, and dolomite. Thickness 40–160 ft (Tysdal, 1990)

Mm **Madison Group (Mississippian)**—Includes Mission Canyon Limestone and underlying Lodgepole Limestone. Mission Canyon Limestone is buff to brown, gray-weathering, bedded, finely crystalline limestone and minor dolomite with some oolitic, bioclastic, and crossbedded layers. Orange solution breccia in upper part. Persistent cliff former. Lodgepole Limestone is more fossiliferous and contains partings of calcareous silty limestone; chert nodules and stringers in lower beds. Total thickness about 1,300–1,450 ft (Tydsal, 1990; Tysdal and Simons, 1985; Simons and others, 1985)

MDt **Three Forks Formation (Lower Mississippian and Upper Devonian) and Jefferson and Maywood Formations (Upper Devonian), undivided**—At top of unit, Three Forks Formation includes, in descending order, Sappington, Trident, and Logan Gulch Members. Sappington Member is gray to yellow, calcareous siltstone, siltstone, and sandstone; only uppermost part is Lower Mississippian in age. Trident Member is gray to yellow dolomite, dolomitic shale, and some limestone. Logan Gulch Member is red, orange, or yellow carbonate-shale breccia. Total thickness 100–250 ft (Simons and others, 1985; Tysdal, 1990; Tysdal and Simons, 1985). Jefferson Formation includes Birdbear Member and underlying Lower Member. Birdbear Member is brown, coarse-grained, ledge-forming dolomite. Lower Member is brown-gray, fine-grained (sucrosic) dolomitic limestone and limestone; dolomite is fetid and has petroliferous odor. Total thickness about 300–450 ft (Simons and others, 1985; Tysdal, 1990; Tysdal and Simons, 1985). Locally in northern part of map area, Maywood Formation is at base of unit; pale-brown-gray, silty, sandy, and pebbly dolomite overlying yellow, dolomitic, sandy, and conglomeratic siltstone on a regolith (or breccia) base; about 34 ft thick (McMannis and Chadwick, 1964; Roberts, 1964f)

OЄu **Ordovician and Cambrian sedimentary rocks, undivided**—In descending order, includes Bighorn(?) Dolomite (Ordovician); Snowy Range Formation (and laterally equivalent Red Lion Formation) and Pilgrim Limestone (Upper Cambrian); and Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone (Middle Cambrian). Bighorn(?) Dolomite is light-gray, dense cryptocrystalline dolomite; about 35 ft thick (Tysdal, 1990). Snowy Range Formation, which includes Grove Creek Limestone, Sage Limestone, and Dry Creek Shale Members, is tan, thin-bedded limestone with irregular-shaped red mottles and interbedded red silty mudstone underlain by green, thin-bedded dolomite and dolomitic mudstone with green clay-shale partings in the upper part and red calcareous siltstone and green sandy clay shale in the lower part; thickness about 300 ft (Tydsal, 1990). Pilgrim Limestone is brown, nodular limestone and dolomitic limestone with partings of dolomitic siltstone and silty dolomite. Limestone is glauconitic and mottled. Mud-pebble conglomerate and oolite beds are common. About 200 ft thick (Tydsal, 1990). Park Shale is gray-green, chippy shale and a few interbeds of limestone, limestone pebble conglomerate, and oolitic limestone. Fossil fragments, burrows, and trace fossils ("worm trails") are common. Thickness about 100 ft (Tydsal, 1990). Meagher Limestone (pronounced "mar") is finely crystalline limestone with irregular-shaped, yellow-orange siltstone mottles. Upper part contains thin partings of calcareous siltstone or green clay shale; lower part contains mottled gray oolitic limestone and gray, finely crystalline limestone. About 500 ft thick (Tydsal, 1990). Wolsey Shale is gray-green, fissile, micaceous clay shale; 65–200 ft thick (Tysdal, 1990). Flathead Sandstone is white, tan, and red-brown, hematitic quartz sandstone; locally glauconitic. Crossbeds, ripple marks, and worm trails are common. Thickness 10–100 ft (Tysdal, 1990)

MzPzu **Mesozoic and Paleozoic sedimentary rocks, undivided**—Limestone, dolomite, chert, shale, siltstone, and sandstone. Mapped only at east edge of northern part of map area (Chadwick, 1982)

mi **Mafic intrusive rocks, undivided (Proterozoic and Archean?)**—Diabase and amphibolite dikes and sills. Diabase sills form cliffs. Northwest-trending diabase dikes in Spanish Peaks area are Proterozoic (K.S. Kellogg, USGS, written commun., June 21, 1996). Plagioclase phenocrysts in a matrix of augite, smaller plagioclase laths, and magnetite. Secondary alteration around associated calcite-quartz veins that commonly contain malachite (Becraft and others, 1966; Erslev, 1981, 1983)

Au **Ultramafic rocks (Archean)**—Serpentinized ultramafic rocks exposed as pods and lenses; generally surrounded by reaction zones (Erslev, 1983)

Am **Metamorphic rocks (Archean)**—Gneiss, schist (biotite, chlorite-hornblende), quartzite, pegmatite, amphibolite, mafic intrusive (diabase and gabbro) rocks, and minor ultramafic rocks. Includes granitic rocks in Mulherin (also known as Mol Heron) Creek area, east-central part of map area

Ad **Dolomitic marble (Archean)**—Coarsely crystalline dolomite with crenulated quartz veins. Locally contains tremolite (Witkind, 1969, 1972)

At **Tremolite marble (Archean)**—Marble composed almost entirely of bladed tremolite crystals. Light gray to gray; extremely resistant; forms topographic ridges. Technically a calc-silicate; tremolite marble terminology from Witkind (1969). Mapped only in southeastern part of map area

Contact—Dashed where approximately located

Normal fault—Dashed where approximately located; dotted where concealed. Ball and bar on downthrown side where direction of movement is known. Opposed arrows indicate sense of lateral displacement where known

Thrust fault—Dotted where concealed. Sawteeth on upper plate

Overturned thrust fault—Sawteeth in direction of dip; base of sawteeth on side of tectonically higher plate. Shown in extreme northeastern part of map area

Madison mylonite zone—Dotted where concealed

Folds—Dashed where approximately located; dotted where concealed. Showing trace of axial plane, direction of dip of limbs, and direction of plunge of axis

Anticline

Overturned anticline

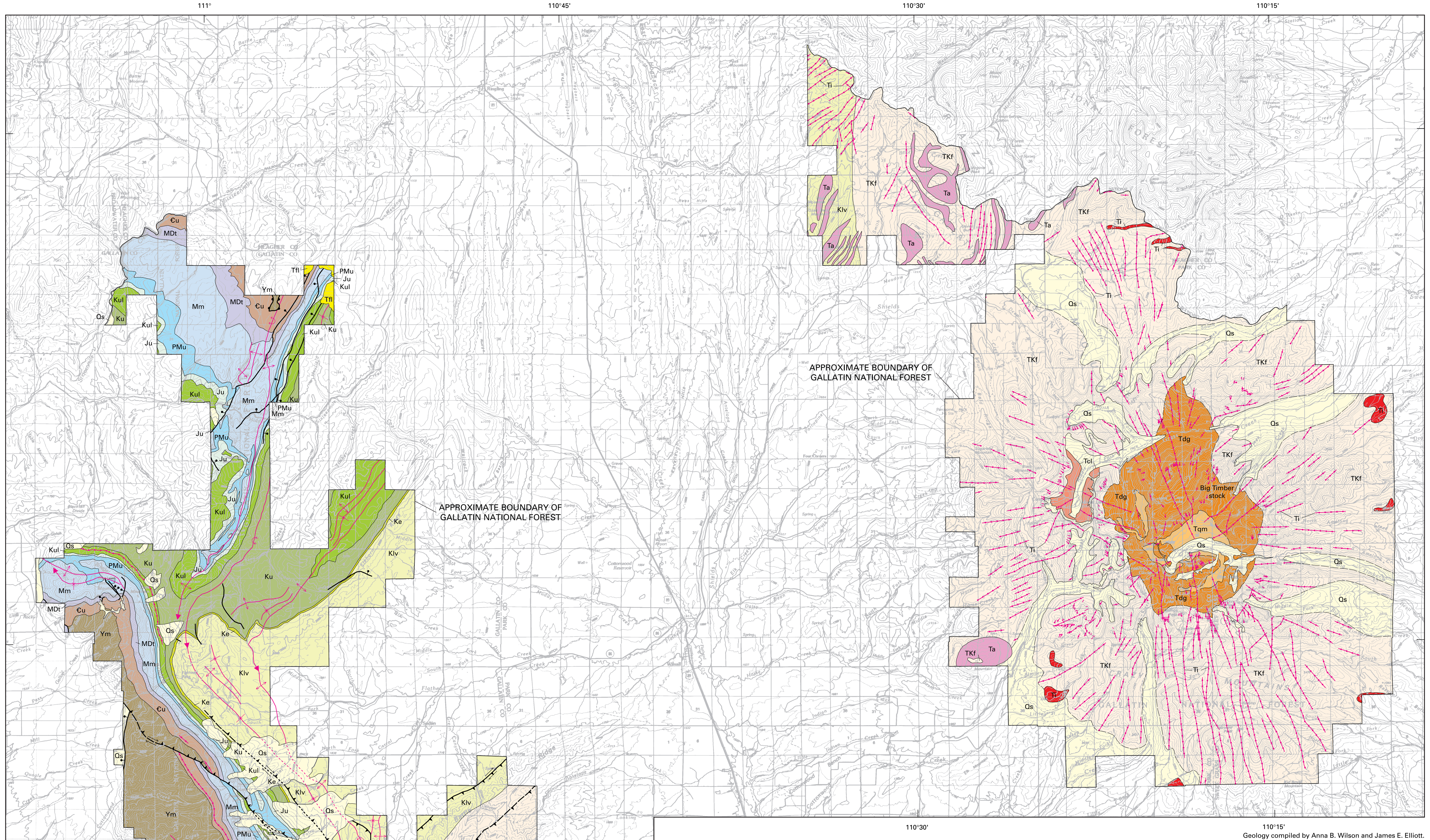
Syncline

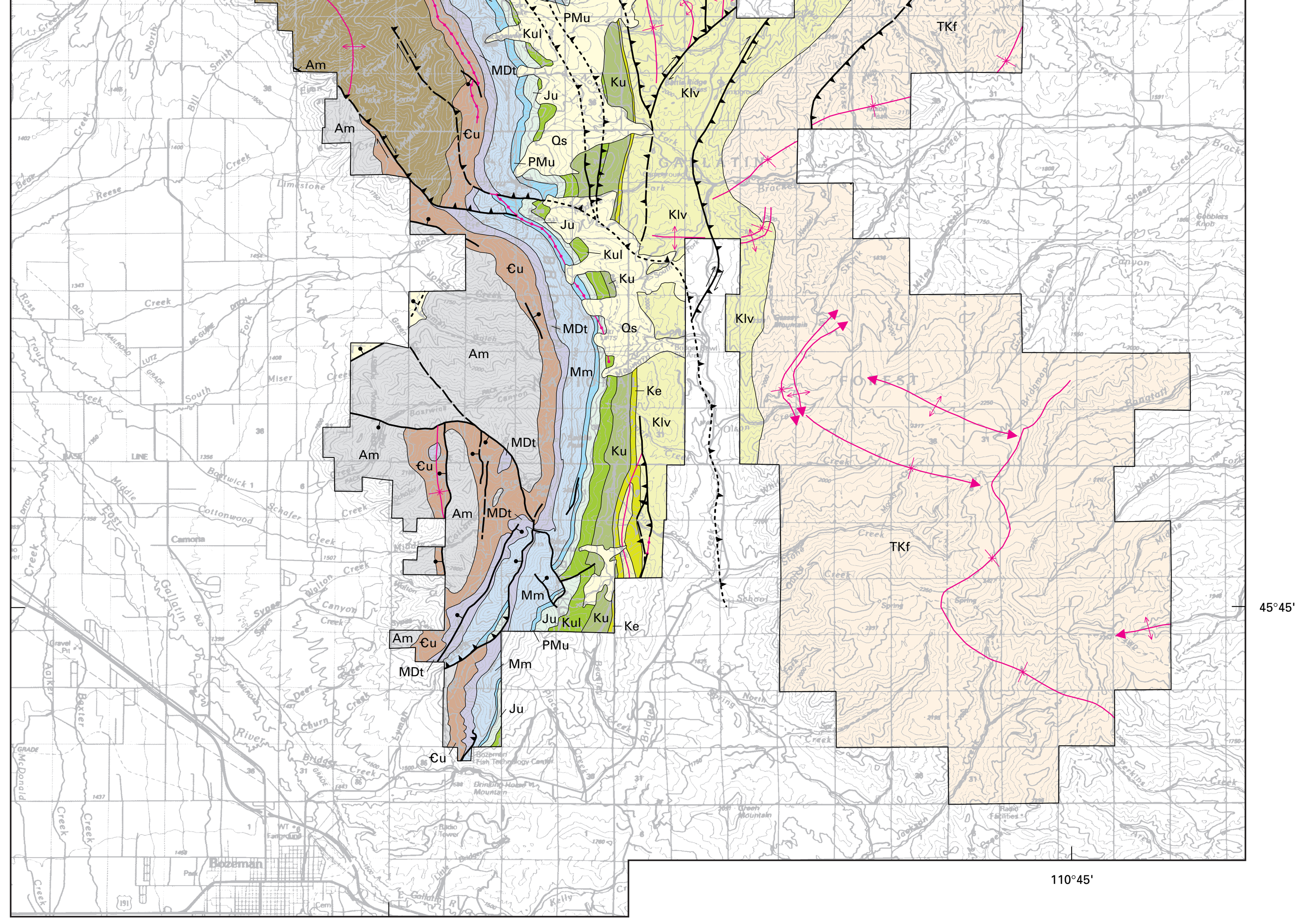
Overturned syncline

Monocline—Arrow points in direction of dip of beds. Only shown once in unit Mm in north-central part of map area

For sale by U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, CO 80225

This map is also available as a PDF at http://greenwood.cr.usgs.gov





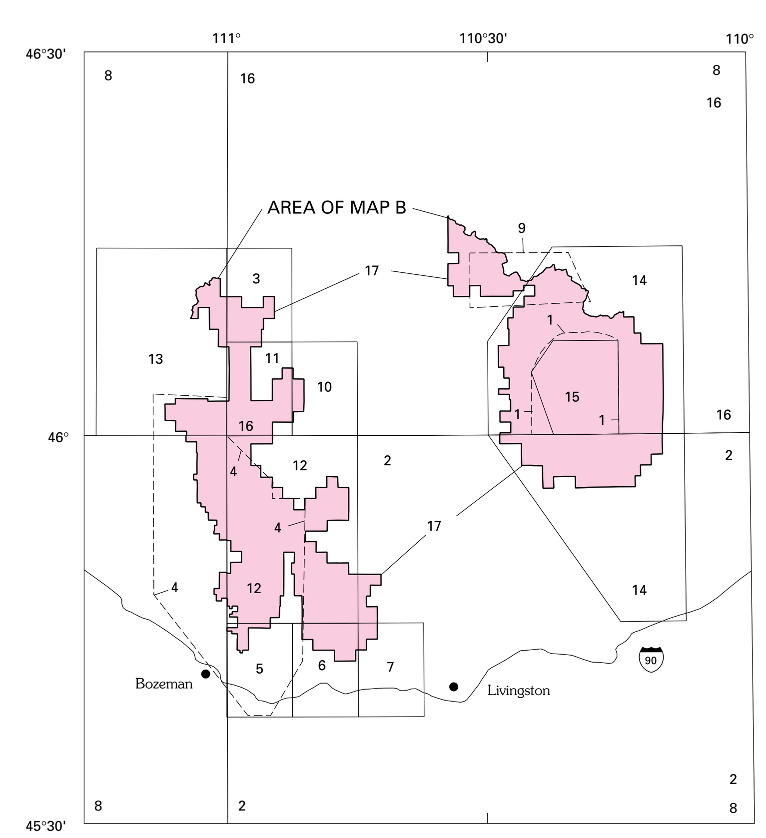
Base from U.S. Geological Survey, 1:100,000, Bozeman, Livingston, Townsend, 1992; Ringling, 1993.
1927 North American Datum. Projection: Universal Transverse Mercator, zone 12.

Geology compiled by Anna B. Wilson and James E. Elliott. See "Index to Sources of Geologic Mapping."
Digital geology by Anna B. Wilson
Editing and digital cartography by Alessandro J. Donatich
Color design by Patricia L. Wilber and Anna B. Wilson

MAP B. NORTHERN PART OF GALLATIN NATIONAL FOREST (BRIDGER RANGE AND CRAZY MOUNTAINS)

SCALE 1:126 720

CONTOUR INTERVAL 50 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



INDEX TO SOURCES OF GEOLOGIC MAPPING

SOURCES OF GEOLOGIC MAPPING

[The following sources were also consulted, but are not shown on the "Index to Sources of Geologic Mapping": Dudas (1990, 1991), Harlan (1986), Lageson and Skipp (1994), Merewether (1960), and Skipp and McGrew (1977)]

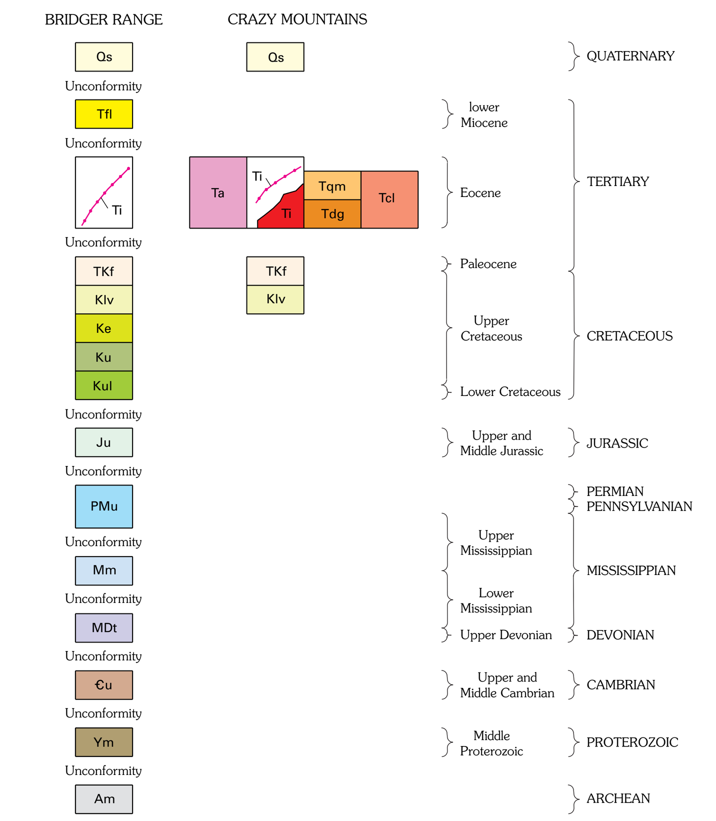
1 du Bray and others (1993)
2 Iddings and Weed (1894)
3 McGrew (1977)
4 McKelvey and others (1959)
4 McMannis (1955)
5 Roberts (1964a)
6 Roberts (1964b)
7 Roberts (1964g)
8 Roberts (1972)
9 Simms (1966)
10 Skipp (1977)
11 Skipp and Hepp (1968)
12 Skipp and McMannis (1971)
13 Skipp and Peterson (1965)
14 Starmer (1972)
15 Tappe (1966)
16 Weed (1899)
17 Wilson and Elliott (1995)

INDEX MAP

GEOLOGIC MAPS OF WESTERN AND NORTHERN PARTS OF GALLATIN NATIONAL FOREST, SOUTH-CENTRAL MONTANA

Compiled by
Anna B. Wilson and James E. Elliott
1997

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

BRIDGER RANGE

Qs **Surficial deposits, undivided (Quaternary)**—Alluvium, colluvium, talus, landslide deposits, rock glaciers, and glacial and glaciofluvial deposits. Only selected major areas, generally exposed for at least 1 mi in a single direction, are shown

Tfl **Fort Logan Formation (lower Miocene)**—Sandy and conglomeratic tuffaceous siltstone with interbedded volcanic ash, freshwater gastropod limestone, and fossiliferous lenses of conglomerate and gravel. Coarse fractions mostly derived from Proterozoic Belt Supergroup and Paleozoic limestone. Shown only in extreme northeast corner of Bridger Range. Exposures more than 100 ft thick; actual thickness not measured (McGrew, 1977)

Ti **Intrusive rocks, undivided (Eocene)**—Dacite, diorite, diabase, and basalt dikes and sills. Diorite dike in northern part of Bridger Range is olive-gray, coarsely crystalline, pyroxene phenocrysts (Skipp and Peterson, 1965); composite dike in southern part of range may be similar in composition (McMannis, 1955). Sills differentiated into upper syenite layer and lower layer of biotite-augite diorite. Thickness 80–200 ft (McMannis, 1955)

TKf **Fort Union Formation (Paleocene and Upper Cretaceous)**—Cliff-forming, massive, nonmarine conglomerate, sandstone, and siltstone; conglomerate clasts derived from pre-Cretaceous rocks. Contains fossil spores, plants, wood, freshwater mollusks, and vertebrates. About 6,600 ft thick (Roberts, 1964b, c; 1972)

Klv **Livingston Group (Upper Cretaceous)**—In descending order, includes Hoppers, Billman Creek, and Sedan Formations. Sedan Formation correlates with Miner Creek and Cokedale Formations, which are exposed in southernmost part of Bridger Range and in a narrow band extending to the east past Cokeville and Livingston (Skipp and McGrew, 1977). Livingston Group is volcaniclastic conglomerate, sandstone, and mudstone; and volcanic flows, sills, tuff, and breccia (Roberts, 1972). Hoppers Formation is purple-gray to gray-green, epiclastic volcanic sandstone, siltstone, mudstone, and conglomerate; 2,400 ft thick (Skipp, 1977). Billman Creek Formation is grayish-red, grayish-green, and gray volcanic mudstone and siltstone interbedded with minor volcanic sandstone, conglomerate, and vitric tuff. Includes freshwater gastropods and dinosaur bones (Skipp, 1977); 2,500–3,000 ft thick (Roberts, 1972; Skipp, 1977). Sedan Formation is primarily greenish-gray, epiclastic volcanic sandstone, mudstone, and conglomerate interbedded with mudflow conglomerate, welded tuff, devitrified silicified vitric tuff, bentonite, and lignitic coal (Skipp and McGrew, 1977). Freshwater mollusks, wood, and dinosaur bones present in upper part of Sedan Formation. Lower part contains ironstone nodules, magnetite-rich beds, volcanic granule-and-pebble conglomerate, and carbonaceous plant material. Lignite coal locally present at base. Sedan Formation about 3,000–4,500 ft thick (Skipp and McGrew, 1977)

Ke **Eagle Sandstone (Upper Cretaceous)**—Upper part is gray, thin- to thick-bedded, very fine grained to conglomeratic, largely calcareous, crossbedded sandstone; calcareous concretions and intercalated coal and shale. Lower part is massive, indurated, ledge-forming, crossbedded sandstone and greenish-gray and grayish-orange volcanic sandstone and conglomerate; intercalated coal, siltstone, and shale. Thickness 150–300 ft (Roberts, 1964a; Skipp, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965)

Ku **Upper Cretaceous sedimentary rocks, undivided**—In descending order, includes Telegraph Creek Formation, Cody Shale, and Frontier Formation. Telegraph Creek Formation is predominantly gray, biotitic, silty shale that contains thin interbeds of fine-grained sandstone, limestone, and altered crystal vitric tuff. Upper part contains large calcareous cannonball concretions; lower part contains pelecypods and ammonites. About 285–400 ft thick (Roberts, 1964a; Skipp, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965). Cody Shale is dark-gray shale and mudstone that contain thin interbeds of gray-green, glauconitic, calcareous to argillaceous, crosslaminated and rippled, fossiliferous (ammonites) sandstone and siltstone; ironstone nodules and cone-in-cone structures occur locally. About 600–1,100 ft thick (McGrew, 1977; Skipp, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965). Frontier Formation is mostly gray, green, or brown, thin- to medium-bedded, fine- to coarse-grained, calcareous to argillaceous, locally crosslaminated, ridge-forming sandstone; light-gray quartz, feldspar, and rock fragments contrast with dark-gray chert grains and give the sandstone a characteristic "salt-and-pepper" appearance. Contains interbeds of mudstone, siltstone, shale, quartzite, chert-pebble conglomerate, siliceous limestone, and fossil oyster banks; mudstone and siltstone intervals form valleys. About 500–700 ft thick (McGrew, 1977; Skipp, 1977; Skipp and Peterson, 1965)

Kul **Upper and Lower Cretaceous sedimentary rocks, undivided**—In descending order, includes Mowry Shale (Upper Cretaceous) and Thermopolis Shale and Kootenai Formation (Lower Cretaceous). Mowry and Thermopolis Shales are dark-gray shaly mudstone and porcellanite interbedded with greenish-gray, medium-grained to very coarse grained, feldspathic, calcareous and argillaceous, thin-bedded sandstone; basal grayish-orange, ledge-forming quartzitic sandstone. Shales total about 600 ft thick (McGrew, 1977; Roberts, 1964a; Skipp, 1977; Skipp and Hepp, 1968). Kootenai Formation is red, gray, and purple hematitic mudstone interbedded with yellowish-gray and grayish-purple, quartzose, medium- to coarse-grained sandstone. Gray, nodular, gastropod-bearing, freshwater limestone common in upper part (about 100 ft below top) and just above basal ledge- and talus-forming, salt-and-pepper sandstone. Lenses of granule- to pebble-size chert conglomerate in basal sandstone. About 200–400 ft thick (McGrew, 1977; Skipp, 1977)

Ju **Jurassic sedimentary rocks, undivided**—Includes Morrison Formation (Upper Jurassic) and underlying Ellis Group (Upper and Middle Jurassic). Ellis Group comprises Swift, Rierdon, and Sawtooth Formations; near Livingston the Sawtooth's lithic equivalent is the Piper Formation. Morrison Formation is red, gray, and purple mudstone and hackly shale intercalated with light-gray, yellowish-brown, and yellowish-orange siltstone and sandstone, some conglomeratic; calcareous, quartzose, commonly crossbedded. Black shale near top; gray freshwater limestone in beds and nodules; thick red mudstone at base. About 200–400 ft thick (McGrew, 1977; Roberts, 1964a; Skipp and Hepp, 1968; Skipp and Peterson, 1965). Ellis Group is light-gray to light-brown, quartzose, calcareous, commonly iron stained sandstone and siltstone, interbedded with gray, fossiliferous, ledge-forming oolitic or sandy limestone and chert-pebble conglomerate. Basal bed grades from chert breccia or chert-pebble conglomerate on the west to thin gray mudstone to fossiliferous limestone on the east. Thickness ranges from 2 to 213 ft (McGrew, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965)

PMu **Permian, Pennsylvanian, and Mississippian sedimentary rocks, undivided**—In descending order, includes Phosphoria (Permian), Quadrant (Pennsylvanian), and Amsden (Lower Pennsylvanian and Upper Mississippian) Formations. Phosphoria Formation (McKelvey and others, 1959) (probably better correlated with Shedhorn Sandstone in this area) consists of a thin (no thicknesses given—presumably not more than several feet thick) section of phosphorite, phosphatic mudstone, carbonaceous mudstone, and chert (McKelvey and others, 1959); mapped with Quadrant Formation by Roberts (1964a, 1972). Quadrant Formation is well-sorted calcareous quartzite to quartzose sandstone; light-gray dolomite in lower part; lower part forms ledges. Thickness 0–150 ft (McGrew, 1977; Roberts, 1964a; Skipp and Hepp, 1968). Amdsen Formation is light-gray, weathering to white, thin- to thick-bedded dolomite. Interbeds of pale-grayish-orange sandstone and siltstone in upper part. Massive red sandstone, gray sandstone, siltstone, and mudstone, and red claystone interbedded with gray argillaceous limestone in lower part; dolomite-limestone breccia at base. About 250–600 ft thick (McGrew, 1977; Skipp and Hepp, 1968)

Mm **Madison Group (Mississippian)**—Includes Mission Canyon Limestone and underlying Lodgepole Limestone. Mission Canyon Limestone is gray, aphanitic to medium-crystalline, cherty, massive, cliff-forming limestone and dolomite. Red-siltstone-filled cavernous zones, limestone breccia beds, and gray dolomite locally in upper part. About 700–1,200 ft thick (McGrew, 1977; Roberts, 1964a; Skipp, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965). Lodgepole Limestone is gray, thin- to medium-bedded, fossiliferous, locally cherty limestone and dolomite; weathers into platy blocks. Red and yellow silty limestone interbeds; thin dark-gray shale at base. Forms step-like ledges. About 500–750 ft thick (McGrew, 1977; Roberts, 1964a; Skipp, 1977; Skipp and Hepp, 1968; Skipp and Peterson, 1965)

MDt **Three Forks Formation (Lower Mississippian and Upper Devonian) and Jefferson Formation (Upper Devonian), undivided**—Three Forks Formation is yellow calcareous siltstone, impure gray fossiliferous limestone, and dark-gray and green mudstone and shale. Thin beds of dolomite in upper part; olive-gray and reddish-brown, calcareous, fossiliferous shale in lower part. Thickness 150–200 ft (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965). Underlying Jefferson Formation is brownish- to olive-gray, thick-bedded to massive, sparsely fossiliferous, fetid dolomite and interbedded gray limestone; local stromatolites. About 400–600 ft thick (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965)

Єu **Cambrian sedimentary rocks, undivided**—In descending order, includes Snowy Range Formation (and laterally equivalent Red Lion Formation) and Pilgrim Limestone (Upper Cambrian); and Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone (Middle Cambrian). Locally may include Devonian Maywood Formation (McGrew, 1977), a red and yellow calcareous siltstone and gray dolomitic limestone (Skipp and Peterson, 1965). Snowy Range Formation is mainly limestone and shale distinguished by rounded limestone pebbles in the Grove Creek Limestone Member; underlain by thick red, gray, and green shale, gray limestone, and siltstone-pebble conglomerate of undivided lower members; bed of columnar limestone locally in lower part of formation (Roberts, 1964a; Skipp and Peterson, 1965). Combined thickness of Maywood and Snowy Range Formations 100–200 ft (Skipp and Peterson, 1965). Pilgrim Limestone is gray, thin-bedded to massive limestone and dolomite; forms cliffs. Oolites, grayish-orange and yellow mottling, and flat-pebble conglomerates are common. Interbeds of greenish-gray shale in lower part; glauconitic and fossiliferous at base. Thickness 350–500 ft (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965). Park Shale is grayish-green to multicolored clay shale; thin beds of argillaceous limestone, siltstone, and sandstone; sparse fossiliferous limestone and limestone-pebble conglomerate in upper part. Nonresistant; forms valleys. Thickness 100–200 ft (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965). Meagher (pronounced "mar") Limestone is thin- to medium-bedded, mottled grayish-orange and medium-gray, fine-grained limestone and yellowish-gray dolomite; locally oolitic; crumpled bedding. Thickness 300–600 ft (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965). Wolsey Shale is olive- to brownish-gray micaceous clay shale; contains gray impure limestone in upper part and fine-grained, thin-bedded, glauconitic sandstone in lower part. Abundant trace fossils ("worm cast" markings). Forms valleys. Thickness 100–500 ft (Roberts, 1964a; Skipp and Peterson, 1965). Flathead Sandstone is yellowish-gray to reddish-gray, fine- to coarse-grained, thin- to thick-bedded, locally crossbedded quartzite and quartz sandstone. Locally conglomeratic in lower part. Very resistant; forms ridges. Thickness 0–300 ft (McGrew, 1977; Roberts, 1964a; Skipp and Peterson, 1965)

Ym **Middle Proterozoic metasedimentary rocks, undifferentiated**—Includes the Spokane and underlying LaHood (formerly North Boulder Group) Formations of the Belt Supergroup. Spokane Formation is light-grayish-green argillite, gray to yellowish-gray quartzite and sandstone, and minor thin-bedded grayish-red limestone; rippled beds are common. Thickness 2,200–3,200 ft (McGrew, 1977). LaHood Formation is dark-greenish-gray, medium-grained to very coarse grained to conglomeratic, micaceous, feldspathic sandstone that contains interbedded dark-gray limestone and impure aphanitic laminated calcareous argillite; sandstone forms about 30 percent of sequence and is most common in upper part; limestone, with cone-in-cone structures, and argillite dominate lower part. More than 2,500 ft thick (Skipp and Peterson, 1965)

Am **Metamorphic rocks (Archean)**—Primarily gneiss. Includes schist, granite, quartzite, pegmatite, amphibolite, and mafic intrusive rocks (Roberts, 1964a)

CRAZY MOUNTAINS

Qs **Surficial deposits, undivided (Quaternary)**—Alluvium, talus, rock glaciers, and glacial deposits. Only selected major areas, generally exposed for at least 1 mi in a single direction, are shown

Ta **Alkalic intrusive rocks (Eocene)**—Mafic alkalic rocks (including malignite, nepheline syenite, analcite syenite, and theralite), trachyte porphyry, and related intrusive rocks. Typically these rocks are sodium rich, silica undersaturated, and strongly alkaline (Harlan, 1986). No plagioclase feldspar and calcic amphibole (Dudas, 1990). Includes dikes, sills, laccoliths, and small stocks

Ti **Intrusive rocks, undivided (Eocene)**—Diorite, diabase, and fine-grained rocks ranging from basalt to rhyolite; includes dikes and sills. Commonly porphyritic; phenocryst composition ranges from 5 to 50 percent. Transitional between alkaline and calc-alkaline compositions. Probably genetically related to quartz monzodiorite phase of Big Timber stock (Tqm) (du Bray and others, 1993). Probably includes alkalic bodies (Ta) on west flank of Crazy Mountains and north of Shields River

Big Timber stock (Eocene)

Tqm **Quartz monzodiorite phase**—Quartz monzonite to granodiorite. Locally contains inclusions of diorite and gabbro (Tdg) along contact. Forms an irregular-shaped mass at center of Big Timber stock (du Bray and others, 1993). $^{40}Ar/^{39}Ar$ ages on biotite: 49.23±0.1 and 49.33±0.12 Ma (S.S. Harlan, USGS, unpub. data, 1996)

Tdg **Diorite and gabbro phase**—Granular diorite and gabbro form main part of Big Timber stock. Locally contains stoped blocks of pyroxene-rich gabbro. Coarser grained and darker in color than quartz monzodiorite phase (Tqm) (du Bray and others, 1993). $^{40}Ar/^{39}Ar$ ages on biotite: 49.2±0.07 and 49.33±0.11 Ma (S.S. Harlan, USGS, unpub. data, 1996)

Tcl **Porphyry of Campfire Lake (Eocene)**—Quartz monzodiorite porphyry, compositionally similar to quartz monzodiorite phase of Big Timber stock (Tqm). Separated from main body of Big Timber stock by sedimentary rocks of Fort Union Formation (TKf). At southern end of area of outcrop, unit has a quenched appearance with plagioclase phenocrysts (2- to 5-mm long) in an aphanitic to glassy groundmass (du Bray and others, 1993)

TKf **Fort Union Formation (Paleocene and Upper Cretaceous)**—Siltstone, mudstone, sandstone, and pebble conglomerate. Unit is mainly hornfels in a several-mile-wide aureole of contact metamorphism adjacent to Big Timber stock (du Bray and others, 1993). Near Livingston, 6,615 ft thick (Roberts, 1972)

Klv **Livingston Group (Upper Cretaceous)**—Volcaniclastic conglomerate, sandstone, and mudstone; tuff and volcanic breccia. Contains flows and sills (Roberts, 1972). Thickness 6,455 ft (Roberts, 1972)

Contact—Dashed where approximately located; dotted where concealed

Normal fault—Dashed where approximately located; dotted where concealed. Ball and bar on downthrown side where direction of movement is known. Opposed arrows indicate sense of lateral displacement where known

Thrust fault—Dashed where approximately located; dotted where concealed. Sawteeth on upper plate. Opposed arrows show sense of lateral displacement

Décollement—Paleocene plane of sliding. Shown only at north end of Bridger Range

Folds—Dashed where approximately located; dotted where concealed. Showing trace of axial plane, direction of dip of limbs, and direction of plunge of axis

Anticline

Overturned anticline

Syncline

Overturned syncline

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