APPENDIX M

PRELIMINARY GEOLOGIC MAP OF THE

BIG TIMBER 30' x 60' QUADRANGLE

SOUTH-CENTRAL MONTANA

by

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Montana Bureau of Mines and Geology

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<u>Revisions</u>
Map: 9/01
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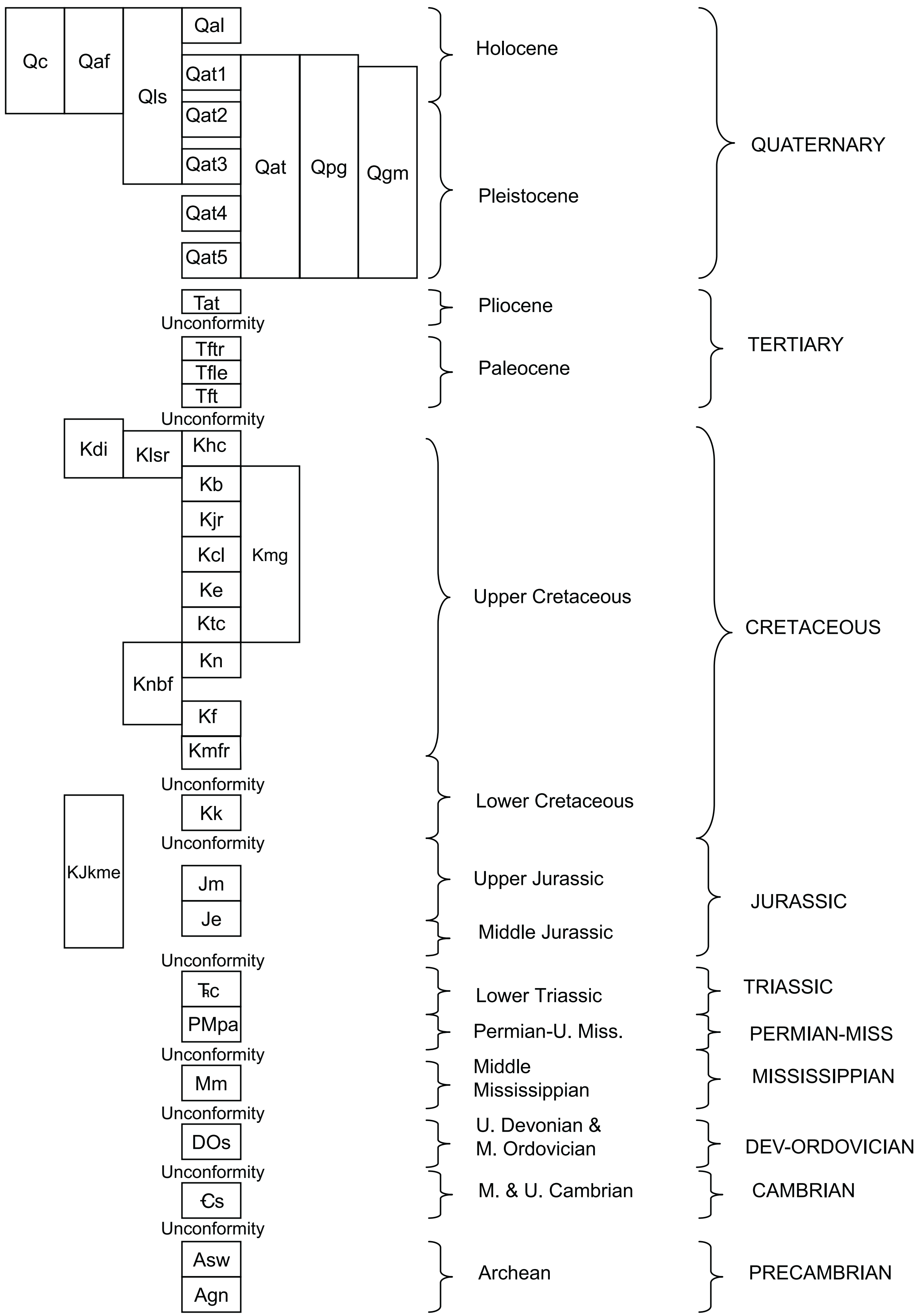
Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U. S. Geological Survey under Contract Number 99-HQ-AG-0130.

CORRELATION OF MAP UNITS–BIG TIMBER 30´ X 60´ QUADRANGLE



GEOLOGIC MAP OF THE BIG TIMBER 30'X 60' 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. Typically thin veneer concealing bedrock, but locally as thick as 30 ft. Commonly grades into Qal. Locally contains well-rounded cobbles derived from alluvial terrace gravel.

Qaf **Alluvial fan deposits (Holocene and Pleistocene)**—Gravel, sand, silt, and clay deposited in fans being formed by modern streams along major valley margins. Display characteristic fan-shaped map pattern and convex upward profile. Typically grade upstream into Qal. Thickness ranges from very thin at toe to as much as 50 ft at head of fans.

Qls **Landslide deposits (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 can occur where slope and moisture content produce unstable conditions.

Qpg **Pediment gravel deposits (Holocene and Pleistocene?)**—Angular and subangular coarse gravel derived from local bedrock; gravel deposits beneath smooth pediment surfaces sloping away from the Crazy Mountains and Beartooth Mountains. About 10 to 30 ft thick.

Qgm Glacial moraine deposits, undivided (Holocene and Pleistocene)—Unsorted mixture of clay-to boulder-size material transported and deposited by glaciers. Characteristic hummocky surface form. Occur 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, igneous rocks, dolomite and limestone.

ALLUVIAL TERRACE GRAVELS

Qat Alluvial 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 Qat1-Qat5.

Qat1 Alluvial gravel, terrace level 1 (Holocene and Pleistocene)—Gravel underlying terraces about 10 to 20 ft above altitude of Qal (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. About 10 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. About 10 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 and minor amounts of sand and silt. Clasts are mainly granitic igneous rocks, granitic gneiss, schist, and quartzite, with much less limestone and sandstone. About 10 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 musch as 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. Calcite cement locally present, especially at base. Thickness ranges from a very thin remnant to about 20 ft.

Tat **Alluvial gravel, terrace level 6 (Pliocene?)**—Gravel underlying terrace about 900 ft above present altitude of rivers. Composed mainly of well-rounded cobbles of granitic gneiss, schist, and quartzite. About 30 to 40 ft thick.

BEDROCK MAP UNITS

Tftr **Tongue River Member, Fort Union Formation (Paleocene)**—Gray to grayish-yellow, fine- to medium-grained sandstone, cross-bedded. Interbedded with brownish-gray carbonaceous shale and siltstone and minor thin coal beds. Sandstones ledge forming, commonly support growths of pine trees. A section about 400 ft thick of this member is present in the map area; top not present in the map area.

Tfle **Lebo Member, Fort Union Formation (Paleocene)**—Predominantly dark-gray to olive shale, locally yellowish-gray claystone; thin, interbedded, yellowish-gray sandstones and siltstone. Typically forms smooth grassy slopes below the Tongue River Member. Thickness 200 to 250 ft.

Tft **Tullock 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 to 600 ft thick.

Khc **Hell Creek (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, MBMG). Total thickness of the formation is about 900 to 1,100 ft.

Kdi **Diorite and diorite porphyry (Upper Cretaceous)—**Dark-gray to medium-gray fine-grained diorite and diorite porphyry, phenocrysts of plagioclase, hornblende, pyroxene, and locally biotite. Occurs as stocks in the Sliderock Mountain area and in the core of a dome in the southwest corner of the map area. Also occurs as dikes and smaller stocks of diorite porphyry and andesite porphyry and trachyandesite. In the area of Ellis Mountain includes xenoliths of rocks derived from the Stillwater Complex. Radiometric age is 74-77 m.y. (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 Sliderock Mountain area. Near the vent zone, adjacent to stock of Kdi, this unit is intruded by innumerable dikes of andesite porphyry and diorite. In distal areas, as near town of Greycliff, clasts are less angular but otherwise similar to breccias elsewhere. Locally contains minor flows of porphyritic andesite and basaltic andesite, with phenocrysts of plagioclase, hornblende, and pyroxene. Thickness is at least 1,000 ft (du Bray and others, 1994).

Kb **Bearpaw Shale (Upper Cretaceous)**—Dark-gray shale, commonly weathering dark-brownish-gray, fissile, fossiliferous, brownish-gray calcareous concretions and nodules are common. Middle part of formation contains numerous thin, mostly greenish-gray bentonite beds, thin sandstone beds common near the top. The thickness is about 100 to 300 ft, thinning westward.

Kjr **Judith River Formation (Upper Cretaceous)**—Interbedded brownish-gray sandy shale and light-brown to pale-yellowish-brown, argillaceous, very-fine to fine-grained lenticular sandstone in beds up to 10 ft thick. A basal, massive cliff-forming sandstone is commonly referred to as the Parkman Sandstone and resembles those in the Eagle Sandstone, Sandstones friable to moderately well indurated, cross-bedded, burrowed to bioturbated, and support growths of pine trees. Greenish-gray and pale-maroon-gray mudstones, poor-quality coal, and easily eroded sandstones occur near the top of the formation. The thickness ranges from 700 to 1000 ft

Kcl **Claggett Shale (Upper Cretaceous)**—Brownish-gray, fissile shale with minor interbeds of light-brownish-gray, very argillaceous sandstone. Light-brownish-gray to light-brown, calcareous concretions common, commonly fossiliferous. The upper contact is gradational and conformable, and is placed at the change to ledge-forming sandstones of the Judith River Formation. Thickness of the formation is 100 to 300 ft, thinning westward.

Ke **Eagle Sandstone (Upper Cretaceous)**—Light-brownish-gray to very-pale Orange, very fine to fine-grained, cross-bedded sandstone, burrowed to bioturbated in part. Locally contains calcareous, light-brown sandstone concretions up to 15 ft in diameter. Up to four sandstone intervals with interbedded shale. Thickness is about 150 ft.

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. Contact with Eagle is placed at the base of the first cliff-forming sandstone. Maximum thickness about 150 ft.

Kmg Montana Group, undivided (Upper Cretaceous)—Includes Bearpaw Shale, Judith River Formation, Claggett Shale, Eagle Sandstone, and Telegraph Creek Formation. Shown only in cross-section.

Kn Niobrara Shale (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. Commonly contains medium-light-gray to pale-yellowish-brown concretions from few inches to 1 or 2 ft in diameter. *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.

Knbf Niobrara through Belle Fourche Formations, undivided (Upper Cretaceous)—Units mapped together where poorly exposed and where thermally metamorphosed in area of intrusive rocks. Mostly medium-gray to dark-gray shales, partly calcareous, occurring between the Telegraph Creek and Frontier Formations. On cross-section includes the Frontier Formation. Thickness approximately 1000 ft

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. Thickness about 350 ft

Kmfr **Mowry Shale through Fall River Sandstone, undivided (Upper Cretaceous)**—Mowry Shale 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 the formation. Thermopolis Shale is predominantly dark-gray, fissile shale, bentonitic shale, containing 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 about 1,300 ft.

Kk **Kootenai Formation (Lower Cretaceous)**—Mostly reddish-brown, olive-gray, and dusky-purple mudstones with interbedded, lenticular, fine- to coarse-grained sandstones. Locally thick, lenticular, fluvial, fine-grained sandstone (Greybull Sandstone) is present at the top. The basal Pryor Conglomerate Member is brown conglomerate and pebbly coarse-grained sandstone, 20 to 60 ft thick. The total thickness of the Kootenai Formation is about 500 ft.

Jm **Morrison Formation (Upper Jurassic)**— Variegated, mainly 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 locally present. Upper contact placed at the base of the Pryor Conglomerate. The basal contact is placed at the top of fossiliferous, calcareous sandstone and coquina of the underlying Swift Formation. Thickness is about 200 ft.

Je **Ellis Group, undivided (Middle and Upper Jurassic)**—Individual formations are not mapped separately; includes the Swift, Rierdon, and Piper Formations. The Swift is interbedded medium gray shale, limestone and calcareous sandstone, fossiliferous. Brownish-gray, fossiliferous, very sandy limestone occurs at the top of the formation, and commonly has 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 crinoids 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 shales. Thickness of the Ellis Group is about 500 ft.

KJkme **Kootenai Formation, Morrison Formation and Ellis Group, undivided (Lower Cretaceous through Middle Jurassic)—**Shown only in cross-section.

TRc **Chugwater Formation (Lower Triassic)**—Interbedded moderate reddish-brown fine-grained sandstone, siltstone, and mudstone. Maximum thickness is about 100 ft, thinning westward to 0 near the west edge of the quadrangle.

PMpa **Phosphoria, Quadrant, and Amsden Formations, undivided (Permian, Pennsylvanian, and Upper Mississippian)—**Formations not mapped separately because of narrow outcrop width. Phosphoria is light-gray limestone, sandstone and quartzite, commonly grayish-pink, cherty; thickness is 50 to 75 ft. 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 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 ft along mountain front. Total thickness of lumped unit is about 500 ft

Mm **Madison Group, undivided (Middle 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. Collapse features and caves are common at the upper karst surface. Thickness of the Madison is 800 to 1,000 ft.

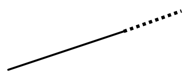
DOs **Sedimentary rocks, undivided (Upper Devonian and Ordovician)**—<u>Jefferson Formation (Devonian):</u> Dolomitic limestone, light brownish gray, fetid, poorly exposed, typically occurs as float. <u>Three Forks Formation (Devonian):</u> Mainly yellowish-weathering, argillaceous limestone and medium-gray shale, very poorly exposed. <u>Big Horn Dolomite (Ordovician)</u>: 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 due to differential weathering. Total thickness of unit is about 600 ft

Ꞓs **Cambrian sedimentary rocks, undivided (Middle and Upper Cambrian)**—Light-reddish 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.

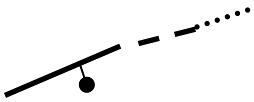
Asw **Stillwater Complex, undivided (Archean)**—Shown only in cross section. Layered ultramafic and mafic rocks from peridotites and pyroxenites at the base (ultramafic series) to gabbros and anorthosite in the upper part (banded series). Maximum exposed thickness in Beartooth Mountains is about 22,000 ft Shown only in cross-section; presence in the subsurface predicted by geophysical data (Kleinkopf, 1985) and by xenoliths in the Lodgepole intrusive (Brozdowski, 1983) and previously unreported xenoliths in the Sliderock Mountain area.

Agn **Granitic gneiss, schist and other metamorphic rocks, undivided (Archean)**—Shown only in cross-section.

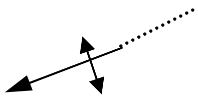
MAP SYMBOLS



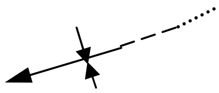
Contact--Dotted where concealed.



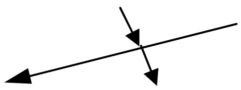
Fault--Dashed where approximately located, dotted where concealed, queried where uncertain. Bar and ball on down-thrown side.



Anticline--Showing trace of axial plane and direction of plunge; dotted where concealed.

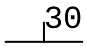


Syncline--Showing trace of axial plane and direction of plunge; dashed where approximately located, dotted where concealed.

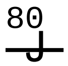


Monocline--Showing trace of axial plane.

Dikes



Strike and Dip of Beds



Overturned Beds

SOURCES OF GEOLOGIC MAPPING
(see index map for locations of maps)

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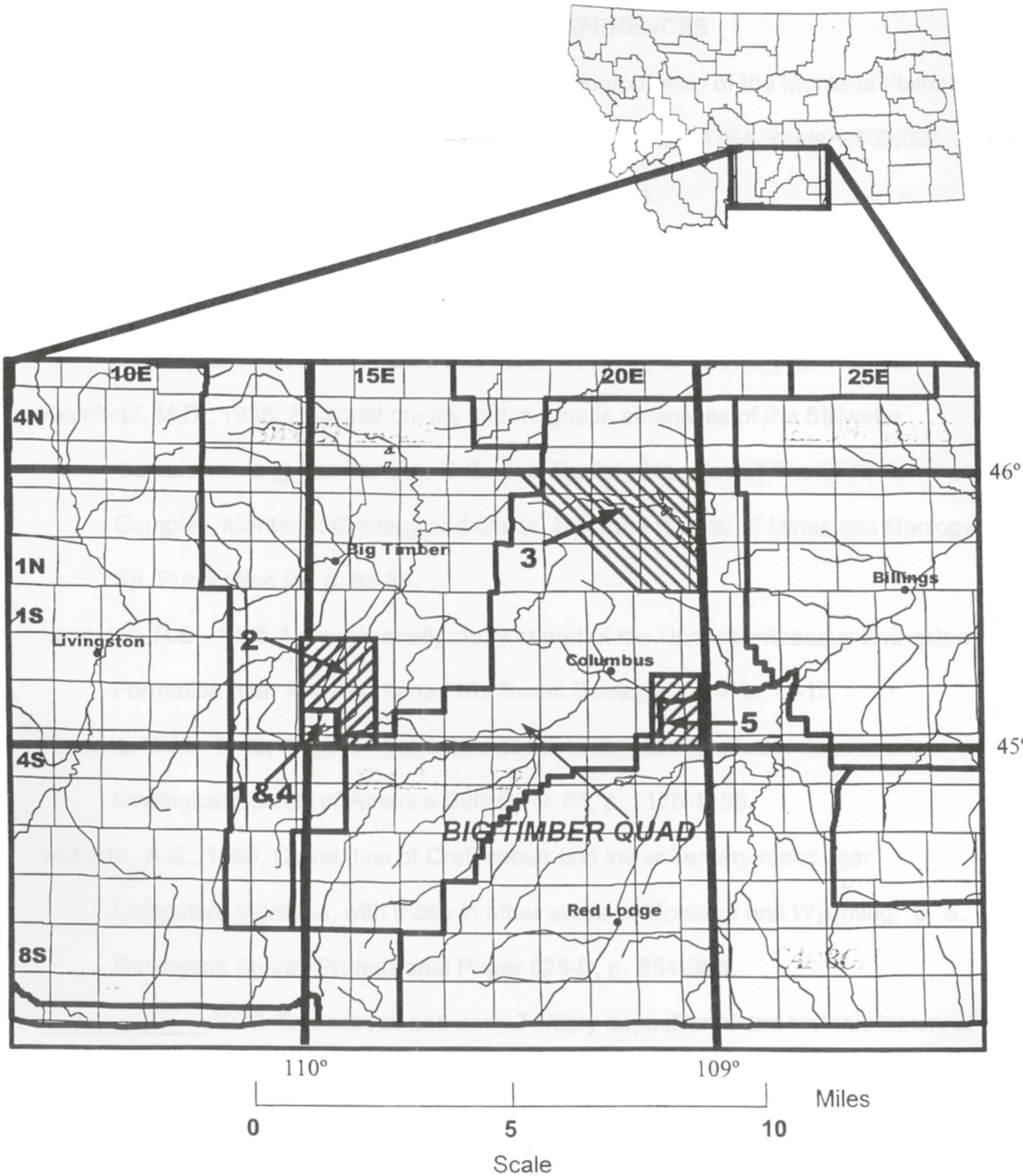

Index Map of Big Timber Quadrangle
and Sources of Geologic Mapping

OTHER GEOLOGIC REFERENCES

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GEOLOGIC MAP OF THE HYSHAM 30'x 60' QUADRANGLE

EASTERN MONTANA

Compiled and mapped by
Susan M. Vuke, Edith M. Wilde, and Robert N. Bergantino

MONTANA BUREAU OF MINES AND GEOLOGY
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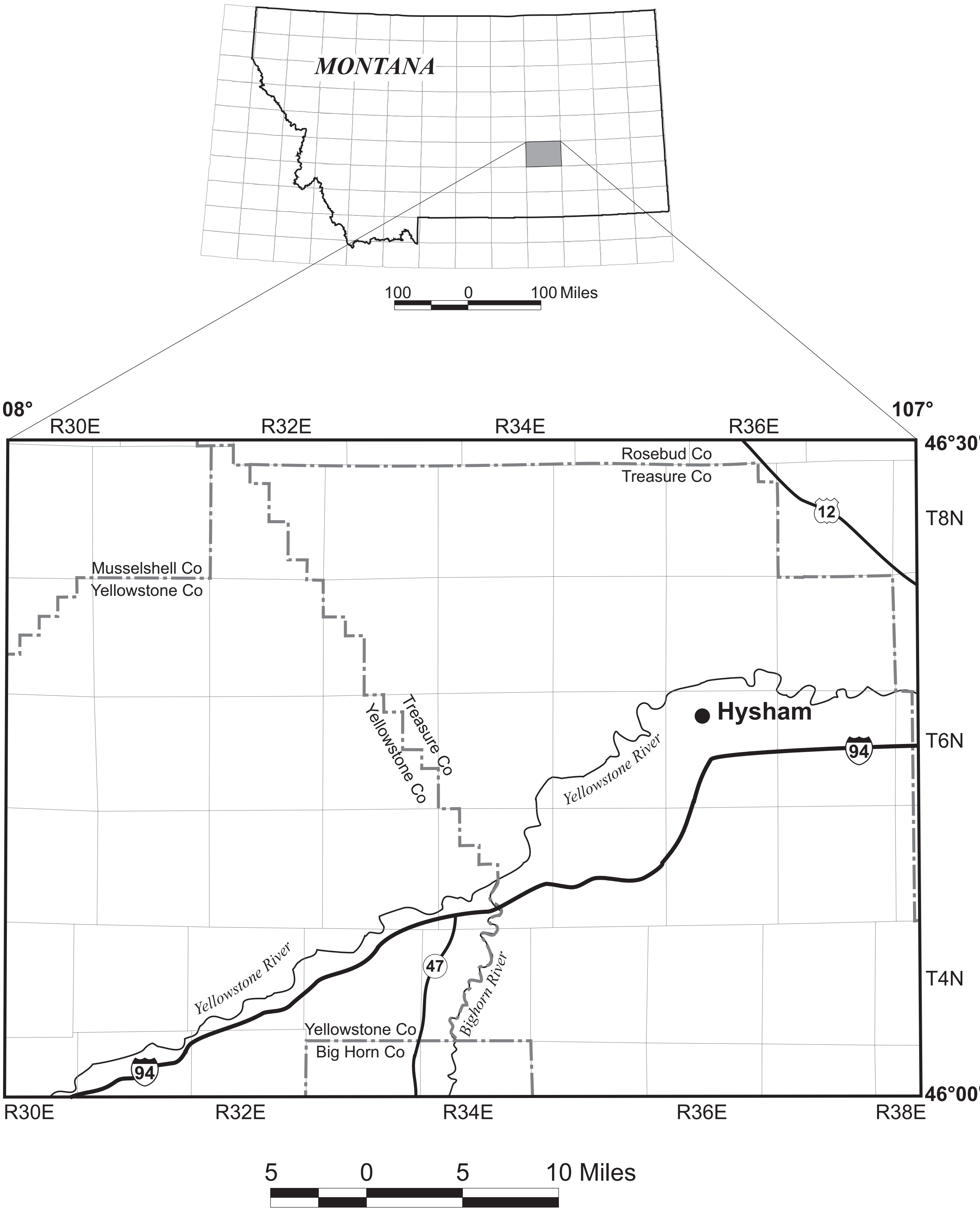
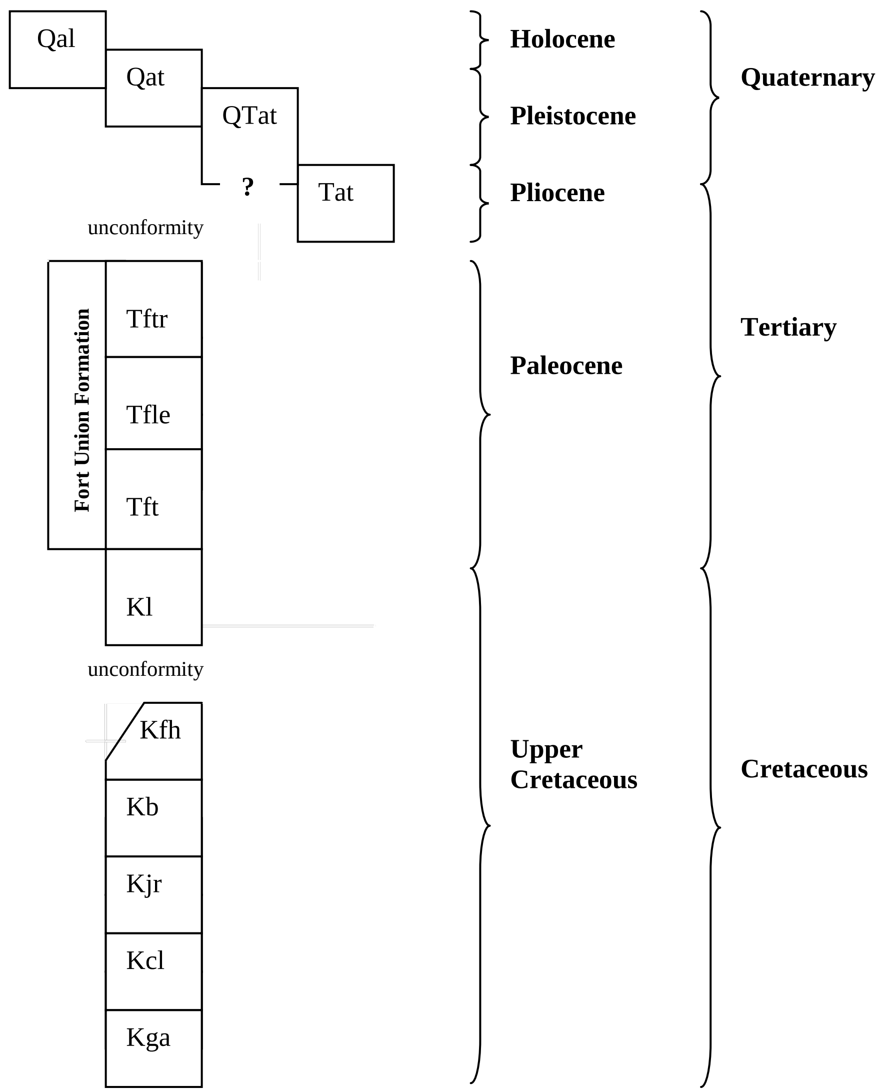


Figure 1. Location of Hysham 30'x60' quadrangle, eastern Montana.

CORRELATION DIAGRAM
HYSHAM 30’ x 60’ QUADRANGLE



GEOLOGIC MAP SOURCES AND INDEX OF 7.5' QUADRANGLES
HYSHAM 30' x 60' QUADRANGLE

108° (west edge) — 107° (east edge); 46°30' (north edge) — 46° (south edge)

Chand-ler Spring 3, 10	Weed Creek West 3, 10	Weed Creek East 6, 10	Rusko-sky Ridge 6	McKon-key Creek 6	Steie Ranch 5, 7	Ahles 5, 7	Vanan-da 2
Pine View 6	Mailbox Hill 6	Mexican Buttes 6	Devil's Kitchen 6	Rancher Ceme-tery 6	Myer 6, 8	Hysham 6, 8	Sanders 6, 8
Bull Moun-tain NW 6	Mud Butte 6	Coal Bank Creek 6	Custer 6	Bighorn 6, 9	Eldering Ranch 6, 9	Scraper Coulee 6, 9	Woods Water 6, 9
Big Mary's Island 4, 6	Bull Moun-tain 1, 6	Waco 1, 6, 8	Mission Creek 1, 6, 8	Marsh Coulee 6, 9	Hope Ranch 6, 9	South Bear Creek 6, 9	Minne-haha Creek North 6, 9

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<u>Entire Map</u>

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HYSHAM 30' x 60' QUADRANGLE
EXPLANATION

Qal **Alluvium (Holocene)—**Light-brown and gray gravel, sand, silt, and clay deposited in stream and river channels and on flood plains. Clasts are well rounded to subrounded. Deposits are poorly to well stratified. Thickness as much as 26 ft under flood plain of Yellowstone River and less than 13 ft under flood plains of tributaries.

Qat **Alluvial terrace deposit (Holocene and Pleistocene)—**Light-gray to light-brown gravel, sand, silt and clay in terrace remnants at elevations from 2 to 275 ft above rivers and streams. Along the Yellowstone River unit includes colluvium. Clasts are generally well sorted and most are well rounded. Deposits are poorly to well stratified and poorly to well sorted. Thickness generally less than 15 ft, but locally as much as 30 ft thick.

QTat **Alluvial terrace deposit (Pleistocene and Pliocene?)—**Light-brown and light-gray gravel and sand at elevations between those of Qat and Tat. Clasts are generally well sorted and most are rounded to subrounded volcanic rocks, crystalline rocks, and quartzite. Deposits are moderately to well sorted. Thickness 20-30 ft.

Tat **Alluvial terrace deposit (Pliocene)—**Light-brown and light-gray gravel and sand. Poorly to moderately well-sorted and stratified with planar and trough cross-bedding. Gravel clasts consist of rounded to subrounded volcanic rocks, crystalline rocks, and quartzite (Agard, 1989). Thickness about 30 feet.

Fort Union Formation (Paleocene)

Tftr **Tongue River Member—**Yellow, orange, or tan, fine- to medium-grained sandstone with thinner interbeds of yellowish-brown, orange, or tan siltstone, light-colored mudstone and clay, brownish-gray carbonaceous shale, and coal. Sand bodies are generally channels that do not persist laterally. Clay dominantly nonswelling. Upper part of member was removed by erosion in map area. As much as 450 ft exposed in map area.

Tfle **Lebo Member—**Gray and greenish-gray smectitic shale and mudstone that contain lenses and interbeds of gray and yellow, very fine to medium-grained, poorly resistant sandstone. Brown ironstone nodules ranging from granule to small boulder size are locally abundant. The Big Dirty coal bed and associated dark-gray or grayish-brown carbonaceous shales are at or near the base of the member; shale contains numerous plant impressions. Thickness of member 150-300 ft.

Tft **Tullock Member—**Light-yellow and light-brown, planar-bedded, very fine to medium-grained sandstone and subordinate gray shale with thin beds of dark-brown to black carbonaceous shale and coal. Locally contains silcrete beds. Thickness of member 200-220 ft.

Kl **Lance Formation (Upper Cretaceous)—**Light-orange or light-tan, medium-grained, massive to cross-bedded sandstone in lenses and channels interbedded with light-gray or greenish-yellow sandy shale. Calcium carbonate-cemented concretions occur locally in fine-grained sandstone. Crossbedded conglomerate lenses at the base contain quartzite and limonite pebbles as much as 1 inch in diameter and armored claystone balls as much as 9 inches in diameter. Thickness 330-525 ft.

Kfh **Fox Hills Formation (Upper Cretaceous)**—Light-brown or light-orange, thin- to thick-bedded, micaceous, fine- to medium-grained sandstone in the upper part and thin-bedded siltstone and silty shale in the lower part. Thickness 0-75 ft.

Kb **Bearpaw Shale (Upper Cretaceous)—**Dark-brownish-gray, montmorillonitic, fissile shale, and mudstone, with numerous thin bentonite beds and zones of calcareous and less common ferruginous concretions. Most bentonite beds are less than 6 inches thick but some are as much as 4 ft thick in the Vananda area (Berg, 1970). Several intervals contain concretions with *Inoceramus*, *Baculites*, and other fossils. Basal Bearpaw contains fissile shale that is rich in organic matter (Heald, 1927). Thickness 900-1500 ft.

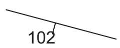
Kjr **Judith River Formation (Upper Cretaceous)—**Upper: Light-gray, thin- to thick-bedded, fine- to medium-grained, cross-bedded sandstone that weathers light-grayish-white, and thin coal lenses. Middle: Dark-gray, thin- to thick-bedded shale unit. Lower: Light-gray, thin- to thick-bedded, fine- to medium-grained sandstone that weathers light-grayish-white, and may contain limonitic concretions. Casts of *Halymenites major* occur throughout the formation and bones of turtles and dinosaurs have been found in the lower concretionary beds (Heald, 1927). Thickness about 245 ft (Heald, 1927).

Kcl **Claggett Shale (Upper Cretaceous)—**Dark-gray, thin-bedded shale with zones of calcareous concretions and bentonite beds. Zone of septarian concretions near top, and 40-ft-thick, cross-bedded sandstone at the top. Prominent bentonite zone (Ardmore bentonite of Gill and Cobban, 1973) at base. Thickness about 435 ft (Heald, 1927).

Kga **Gammon Shale (Upper Cretaceous)**—Light-gray shale, silty shale, and lesser siltstone and fine-grained sandstone, with thin beds of calcareous concretions, ferruginous concretions, and bentonite scattered throughout the formation. Only the uppermost 20 ft exposed in the northeast corner of the map.

MAP SYMBOLS
HYSHAM 30'x 60' QUADRANGLE

Contact—Dotted where concealed.



Strike and dip of bedding—Number indicates amount of dip in degrees.

Fault—Ball and bar on downthrown side, dotted where concealed fault interpreted from apparent offset of stratigraphic units.

(red)

Anticline—Showing trace of axial plane; dashed where approximately located; dotted where concealed.

(red)

Syncline— Showing trace of axial plane; dashed where approximately located; dotted where concealed.

(purple)

Silcrete bed—Siliceous paleosol bed in Tullock Member of Fort Union Formation.

(red)

Dike—Light- to dark-greenish-brown, extremely weathered porphyritic lamprophyre a few inches to a few feet thick (E.S. Larsen in Heald, 1927).

Diatreme — Froze-to-Death Butte lamproitic pipe-like intusion and associated small dikes. Contains sedimentary senoliths (Doden, 1997).

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GEOLOGIC MAP OF THE FORSYTH 30' x 60' QUADRANGLE,

EASTERN MONTANA

Compiled and mapped by Susan M. Vuke, Robert N. Bergantino,
Roger B. Colton, Edith M. Wilde, and Edward L. Heffern

Montana Bureau of Mines and Geology
Open File Report MBMG 425

2001

Map revised: 11/07

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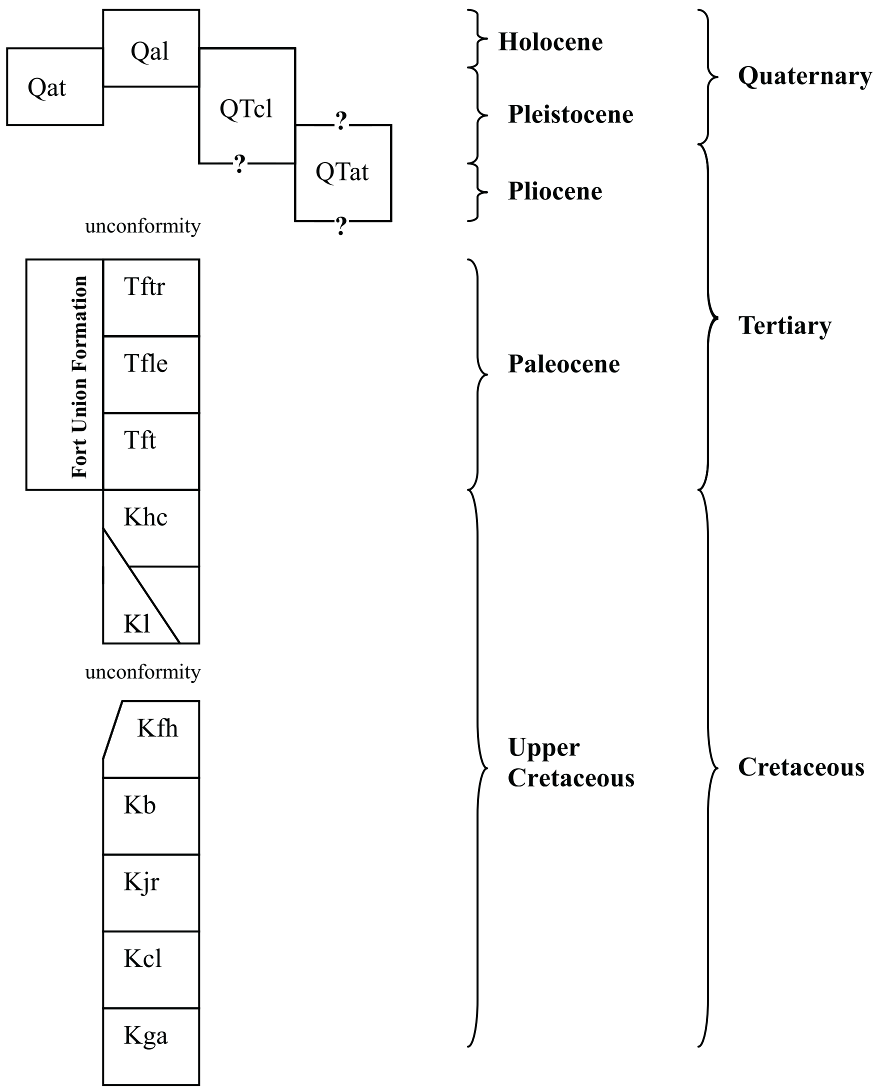
CORRELATION DIAGRAM
FORSYTH 30' x 60' QUADRANGLE



DESCRIPTION OF MAP UNITS
FORSYTH 30'x 60' QUADRANGLE

Note: Thicknesses are given in feet because original field maps were on 7.5' quadrangles with contour intervals in feet. To convert feet to meters (the contour interval unit on this map) multiply feet x 0.3048.

Qal **Alluvium (Holocene)**—Light-brown and gray gravel, sand, silt, and clay deposited in stream and river channels and on flood plains. Clasts are well rounded to subrounded. Deposits are poorly to well stratified. Thickness as much as 26 ft under flood plain of Yellowstone River and less than 13 ft under flood plains of tributaries.

Qat **Alluvial terrace deposit (Holocene and Pleistocene)**—Light-gray to light-brown gravel, sand, silt and clay in terrace remnants at elevations from 2 to 350 ft above rivers and streams. Along the Yellowstone River unit includes colluvium and a few small alluvial fan deposits. Clasts are generally well sorted and most are well rounded. Deposits are poorly to well stratified and poorly to well sorted. Thickness generally less than 15 ft, but locally as much as 50 ft.

QTcl **Clinker (Holocene, Pleistocene, and Pliocene?)**—Red, pink, orange, black, and yellow, very resistant metamorphosed sandstone, siltstone, and shale of the Fort Union Formation. Bedrock was baked by natural burning of underlying coal, and collapsed into voids created by burning. Locally, baked rock was melted and fused to form buchite, a black, glassy, vesicular or scoriaceous rock. Thickness generally about 20 ft, but locally as much as 50 ft.

QTat **Alluvial terrace deposit (Pleistocene and Pliocene?)**—Light-brown and light-gray gravel and sand at elevations generally from 2,880–3710 ft. Clasts are generally well sorted and most are well rounded. Deposits are moderately to well sorted. Thickness about 30 ft.

Fort Union Formation (Paleocene)

Tftr Tongue River Member—Yellow, orange, or tan, fine-grained sandstone with thinner interbeds of yellowish brown, orange, or tan siltstone, and light-colored mudstone and clay. Clay dominantly nonswelling. Sandstone may contain rare lenses as much as 50 ft long (Smith, 1956) of intraformational breccia with pebble- and cobble-size clasts of sandstone. In the map area, the Rosebud, McKay, Terret, and Burley are the most prominent of the coal beds in this member. In part of the map area (shown with hachure pattern) the lower part of the member contains a unit characterized by thin, orange silty limestone beds that serve as caprocks and are associated with light-colored or white siltstone and mudstone beds that may contain white- or light gray-weathered silcrete and other paleosols. The silcrete and other paleosols characteristically contain molds of plant stems and roots, and range from 1 to 6 inches thick. Upper part of member was removed by erosion in map area. Thickness of as much as 540 ft exposed in map area.

Tfle Lebo Member**—**Gray, smectitic shale and mudstone that contains lenses of gray and yellow, very fine- to medium-grained sandstone, and ironstone concretion zones from 1 to 12 inches thick. The Big Dirty coal bed is at or near the base of the member. In part of the map area (shown with hachure pattern) the upper part of the member contains a unit characterized by thin, orange silty limestone beds that serve as caprocks, and light-colored or white siltstone and mudstone beds that may contain white- or light gray-weathered silcrete and other paleosols. The silcrete and other paleosols characteristically contain molds of plant stems and roots, and range from 1 to 6 inches thick. Thickness of member 95–200 ft.

Tft Tullock Member**—**Light-yellow and light-brown, planar-bedded very fine- to medium-grained sandstone and much less gray shale. Contains two or three coal beds in the upper 110 ft of member, and in many places, a coal bed at the base. Thickness of member 240–260 ft.

Khc **Hell Creek Formation (Upper Cretaceous)**—Dominantly gray and grayish brown sandstone, smectitic, silty greenish brown or gray shale, and mudstone, and a few thin beds of lignite or carbonaceous shale. Sandstone is fine- or medium-grained. Calcium carbonate-cemented concretions are typical in the fine-grained sandstone. Thickness 200–300 ft.

Kl **Lance Formation (Upper Cretaceous)—**Light-orange or light-tan, medium-grained, massive to crossbedded sandstone in lenses and channels interbedded with light-gray or greenish yellow sandy shale. Crossbedded conglomerate lenses at the base contain quartzite and limonite pebbles up to 1 inch in diameter and armored claystone balls up to 9 inches in diameter. Thickness 0–300 ft.

Kfh **Fox Hills Formation (Upper Cretaceous)**—Light-brown or light-orange, thin- to thick-bedded, micaceous, fine- to medium-grained sandstone in the upper part and thin-bedded siltstone and silty shale in the lower part. Thickness 0–200 ft.

Kb **Bearpaw Shale (Upper Cretaceous)—**Dark brownish gray, montmorillonitic fissile shale, with numerous thin bentonite beds and zones of calcareous and less common ferruginous concretions. Most bentonite beds are less than 6 inches thick but some are as much as 4 feet thick in the Vananda area just west of the map area (Berg, 1970). Thickness 800–950 ft.

Kjr **Judith River Formation (Upper Cretaceous)**—Upper light-gray, thin- to thick-bedded, fine- to medium-grained sandstone that weathers light grayish white from 72 to 92 ft thick. Middle dark-gray thin- to thick-bedded shale unit about 130 ft thick. Lower light-gray thin- to thick-bedded fine- to medium-grained sandstone that weathers light grayish white. Thickness about 100 ft.

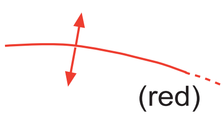
Kcl **Claggett Shale (Upper Cretaceous)**—Dark-gray, thin-bedded shale with zones of calcareous concretions and bentonite beds. Zone of septarian concretions at top about three feet thick. Prominent bentonite zone (Ardmore bentonite of Gill and Cobban, 1973) at base. Thickness 270–580 ft.

Kga **Gammon Shale (Upper Cretaceous)**—Light-gray shale, silty shale, and lesser siltstone and fine-grained sandstone, with thin beds of calcareous concretions, ferruginous concretions, and bentonite scattered throughout the formation. Lower part of formation not exposed in map area. Exposed thickness 250 ft.

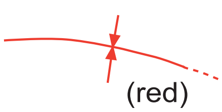
MAP SYMBOLS

Contact—Dotted where concealed.

Strike and dip of bedding—Indicating direction and amount of dip.



Anticline—Showing trace of axial plane; dotted where concealed.



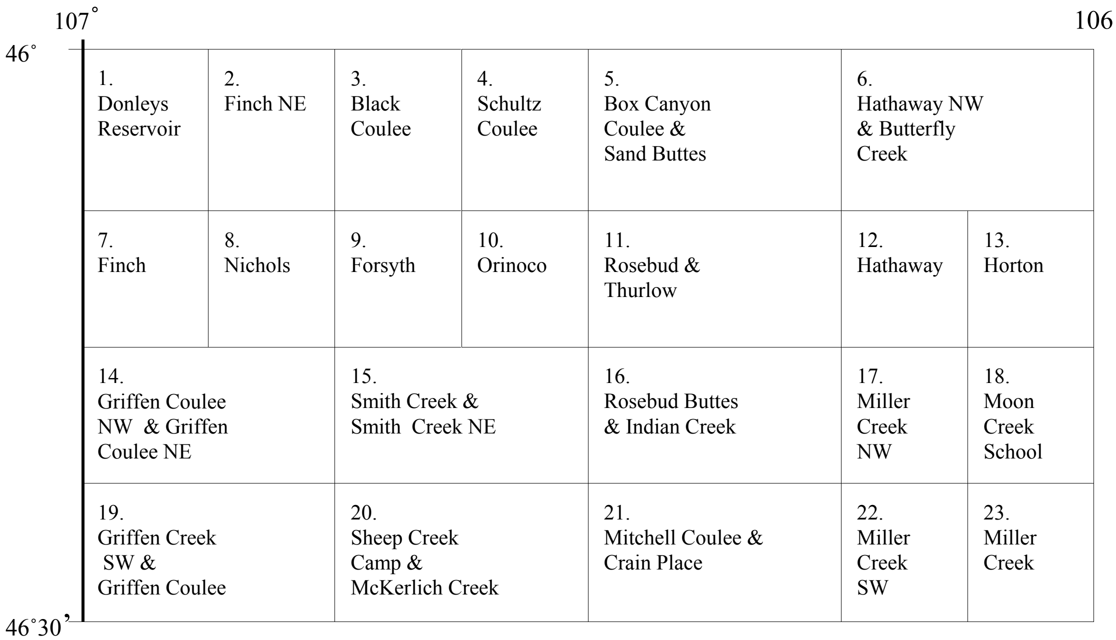
Syncline—Showing trace of axial plane; dotted where concealed.

Fault—Ball and bar on downthrown side.

Paleosol interval—Zone of thin orange limestone beds, light-colored beds, and paleosol beds including silcrete.

Silcrete bed—Siliceous paleosol bed within paleosol interval.

GEOLOGIC MAP SOURCES AND INDEX OF 7.5' QUADRANGLES
FORSYTH 30’ x 60’ QUADRANGLE



Numbers below correspond to numbers on 7.5’ quadrangle index on previous page.
<u>Map scale 1:24,000 unless otherwise indicated.</u>

1. Colton, R.B., Klockenbrink, J.L., and Grout, M.A., 1987b.
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Field mapping by above authors, E.M. Wilde, and S.M. Vuke.

<u>Entire quadrangle</u>
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FORSYTH 30' x 60' QUADRANGLE
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