GEOLOGIC MAP OF THE ZORTMAN 30' x 60' QUADRANGLE

CENTRAL MONTANA

Compiled and Mapped

by

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SUMMARY

The Zortman quadrangle is located in central Montana (figure 1). It includes the Little Rocky Mountains in the northern map area and broad plains to the south that are underlain by the Bearpaw Shale and bisected by the east-flowing Missouri River. The central Little Rocky Mountains are cored by several large Tertiary syenite intrusives. Several of the satellite domes forming foothills south and east of the mountains are also cored by syenite. The central mountains and associated domes are flanked by Precambrian crystalline rocks and Paleozoic and Mesozoic sedimentary rocks. A thick Cretaceous section forms the outer sequence. In the western map area and approaching the west flank of the Little Rocky Mountains are intersecting ridges of the Judith River Formation. These ridges are the eastern extent of the faulted folds associated with the gravity-slide tectonics that dominate the area surrounding the Bears Paw Mountains to the west in the adjacent Winifred quadrangle (Wilde and Porter, 2001).

Alluvial deposits that are present across broad benches on the south and west flanks of the Little Rocky Mountains have not been mapped for this report. They are shown by Knechtel (1959) as alluvial gravels of Quaternary and/or Tertiary age.

This report combines the earlier mapping of Reeves (1924), Knechtel (1959), Hearn, Jr., (1979), Lechner (1979), and the U. S. Geological Survey (1979) (figure 1) with new mapping by the authors, primarily of Cretaceous units. Principal among these sources is the 1959 map by Knechtel of the Little Rocky Mountains and encircling foothills; modifications of the Knechtel map by the present authors mainly involve the combining of rock units into mappable units at the 1:100,000 scale. Units shown on earlier-published maps have been integrated with recent work completed by MBMG in adjacent 1:100,000-scale quadrangles (figure 1). This integration applies principally to the Cretaceous section below the base of the Eagle Sandstone in the Little Rocky Mountains area in the northern part of the map.

Cretaceous Stratigraphy Below the Eagle Sandstone

Stratigraphic terminology used by Knechtel (1959) for the Cretaceous section below the Eagle Sandstone and above the Kootenai Formation has been partly changed to follow more recent published maps of that interval. Following the work of Cobban (1951, 1953) and Johnson and Smith (1964), Porter and Wilde (1993; revised 1999) retained the Black Hills terminology for this interval in the south-adjacent Winnett quadrangle.

The Mowry Shale is a key unit in the Cretaceous section in this area because of its relative resistance and distinctive bluish-white-weathering, fish-scale-bearing, siltstone lithology within the thick marine shale section between the Eagle Sandstone and the Kootenai Formation. Knechtel (1959) recognized and mapped the Mowry.

Below the Mowry, Knechtel (1959) mapped the Thermopolis Shale within which he included, but did not name, equivalents to the Skull Creek Shale and Shell Creek Shale and the medial sandstone equivalent to the informally named sandy member of the Thermopolis (Porter and Wilde, 1993, revised 1999). He named this medial sandstone the Cyprian Sandstone, noting that its stratigraphic position suggested it may be equivalent to the Muddy Sandstone of eastern and southeastern Montana. The present authors agree, but have retained the name Cyprian because details of the stratigraphic position of sandstones in this middle Thermopolis

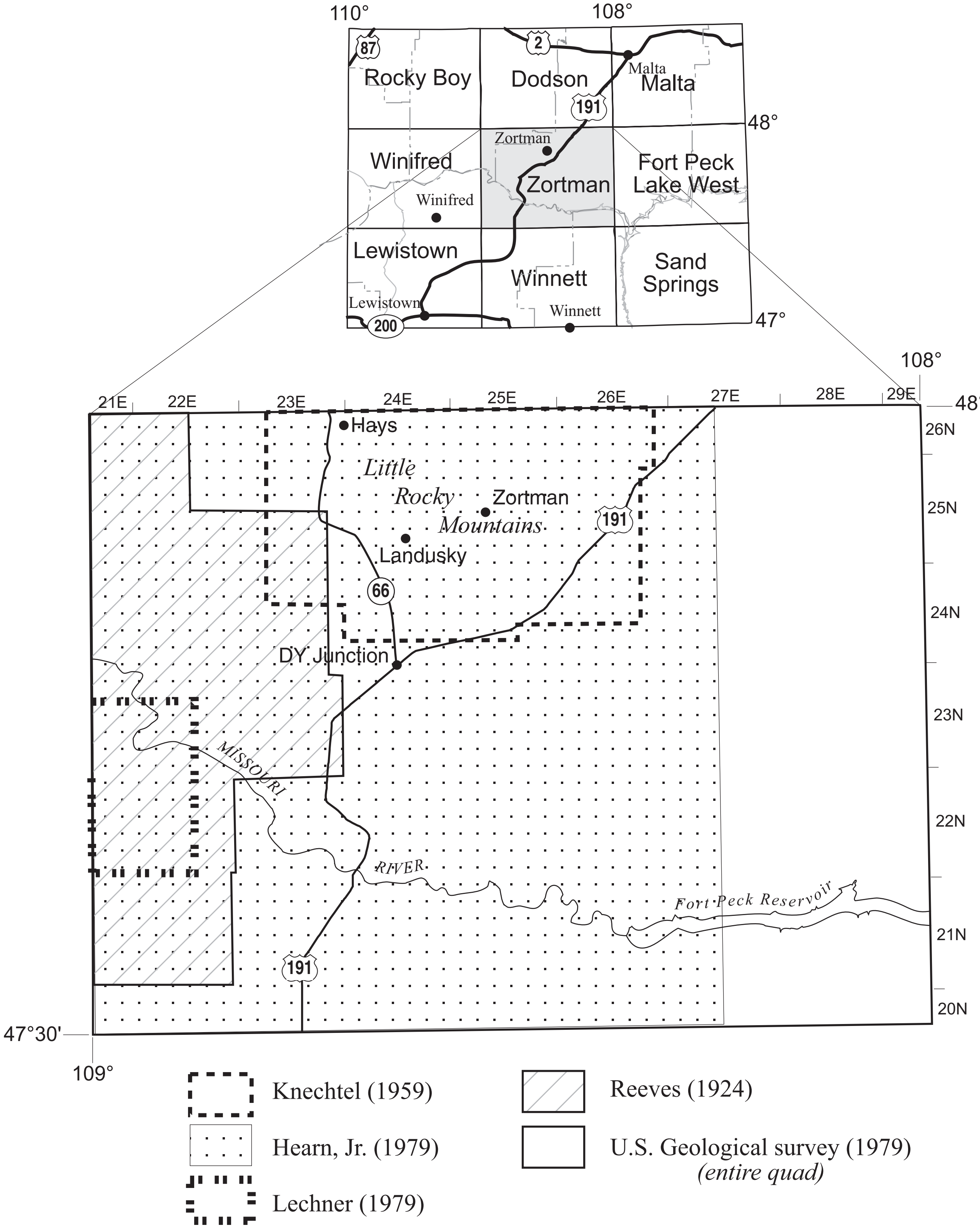

Figure 1. Location map for Zortman quadrangle showing areas covered by earlier geologic maps within the quadrangle (see Sources of Previous Geologic Mapping), and location of adjacent geologic maps published by MBMG.

interval are regionally complex; the Cyprian Sandstone has been interpreted by Porter and others (1997) as a nonmarine sandstone lying above a basin-wide unconformity, while the Muddy Sandstone farther southeast has units that lie both above and below this unconformity.

Above the Mowry Shale, Knechtel (1959) continued use of the term Warm Creek Shale, first proposed by Collier and Cathcart (1922), to include the remaining section from top of the Mowry to base of the Eagle. He recognized the lower Warm Creek as the Belle Fourche Shale (his Kwb unit), the middle Warm Creek as containing the combined Mosby Sandstone and Greenhorn Formation (his Kwg unit), and the upper Warm Creek as containing the Carlile, Niobrara, and Telegraph Creek Formations (his Kwu unit). The present authors, also recognizing these earlier-named formations, have not used the term Warm Springs Shale but rather, applied the older formation names, even when formations are combined in mapping because of poor exposures. Additionally, following Rice (1984), the Mosby Sandstone is recognized as an upper member of the Belle Fourche Shale, not a lower member of the overlying Greenhorn Formation. In the present quadrangle area, the Greenhorn Formation and the Mosby Member of the Belle Fourche form a distinctive interval, about 60 feet thick, within the approximately 1,750-foot section of marine shale and sandstone below the Eagle. Thus, the two are combined for mapping purposes and are indicated on the map as a dashed line labeled Kgrm. The underlying map unit is the lower shale member, informal, of the Belle Fourche Shale (Kbfl); the overlying map unit is the combined Carlile, Niobrara and Telegraph Creek Formations (Ktca).

Cross Section A-A’

Cross section A-A’ crosses a number of folds and faulted folds in the west area of the map. The overall tectonic regime for these presumed gravity-slide-generated features is one of tension at the point of separation from the Bears Paw Mountains to the northwest of the map area, but of compression within the very large blocks that slid southeastward onto the adjacent plains within the map area. Drill hole data confirm that the glide planes for this movement occur almost entirely within the Upper Cretaceous shales of the Niobrara and Carlile Formations (Kn + Kca unit on cross section; lower part of Ktca unit on map). In this compressional regime, fault planes would dip back toward the mountain front, in this case northwestward. The dips of fault planes intersected along section A-A’ are conjectural only; no data have been reported by us or by previous authors. However, faults exposed along the Missouri River in the adjacent Winifred quadrangle appear to dip as much as 40 degrees or more.

The gradient of the glide planes beneath the gravity slide blocks has been investigated based on drill hole data: structure contours on the top of the Greenhorn limestone that lies just beneath the deepest known glide plane (in the lower Carlile Formation) indicate a gradient of 150 to 200 feet per mile (1.75 degrees) within 10 miles of the mountain front, and 30 to 60 feet per mile (0.5 degrees) farther away (Hearn,1976). Faults within the slide blocks presumably become subparallel with or merge with the glide plane at depth. On cross section A-A’, the contact at the base of the Niobrara-Carlile interval (Kn +Kca) probably approximates the glide plane beneath the gravity-slide block traversed by the line of section. A few miles northeast of cross section A-A’ is a northwest-trending fault along which the motion is inferred to be strike slip. Reeves (1924) considers this fault to be the boundary between two very large gravity-slide blocks.

Around the entire Bears Paw Mountains region, the horizontal displacement created by the plainsward sliding apparently has been accommodated by (1) northward tensional backsliding of the hanging-walls of many faults, and (2) “wrinkling” of broad areas into long, subparallel folds. Within a discrete gravity-slide block these two strains are intermixed with the reverse faults that reflect the original compressional regime. On cross section A-A’ all but one of the intersected faults are reverse in nature. Another possible mechanism for accommodating the horizontal displacement would be the up-ramping of strata against a stable block at the distal edge of the slide block, in the manner of a landslide. If observed, this up-ramping would be represented by the most distal fault that places older beds up against apparently undisturbed Bearpaw Shale. This relationship is observed on cross section A-A’ at the southeastern edge of the faulted terrain.

ACKNOWLEDGMENTS

The authors thank Dr. B. Carter Hearn, Jr., of the U. S. Geological Survey in Reston, VA for helpful discussions on the occurrence of Tertiary intrusive bodies throughout the region.

Correlation Chart of Map Units
Zortman 30’ x 60’ Quadrangle

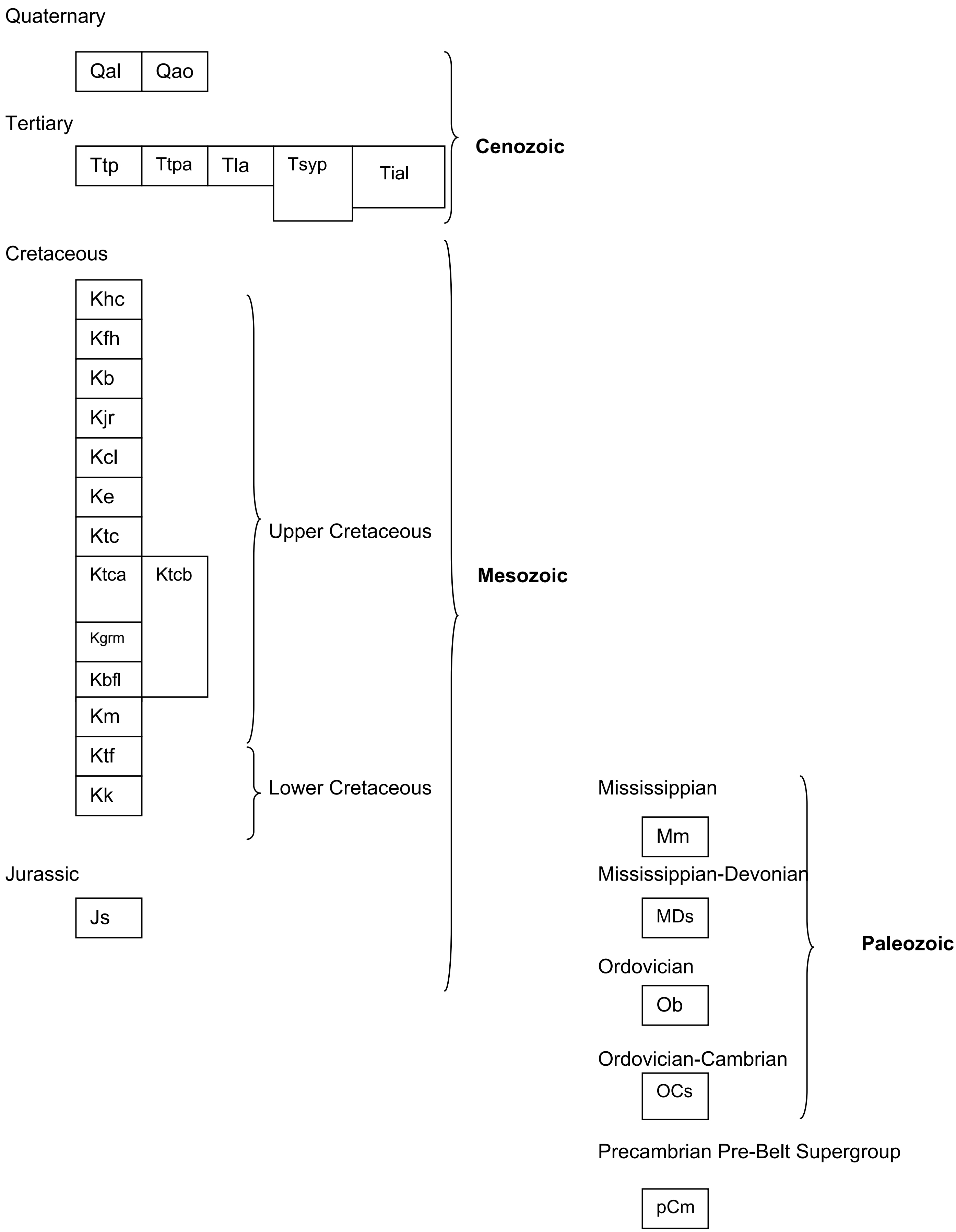

Figure 2. Correlation chart of map units.

DESCRIPTION OF MAP UNITS

QUATERNARY

Qal FLOOD PLAIN AND CHANNEL ALLUVIUM (HOLOCENE) — Yellowish tan and grayish tan, poorly to well stratified gravel, sand, silt, and clay deposited in flood plains and channels of modern streams. Locally includes some slightly older Holocene terrace alluvium. Thickness not measured.

Qao OLDER ALLUVIUM (HOLOCENE) — Light-yellowish gray-weathering deposits of unconsolidated clay, silt, sand, and some fine gravel; moderately to well sorted; occurs along modern drainages, generally slightly above modern alluvial flood plains; includes some terrace deposits; poorly exposed except where cut by stream erosion; generally covered by thin soils. Older alluvial deposits on dissected pediment surfaces surrounding Little Rocky Mountains not mapped. They are shown by Knechtel (1959) as alluvial gravels of Quaternary and/or Tertiary age. Thicknesses not measured.

TERTIARY

Intrusive Rocks (from Knechtel, 1959)

Ttp TRACHYTE PORPHYRY DIKES. Cutting major syenite intrusive centers of Little Rocky Mountains (see Map Symbols).

Ttpa AEGERINE TRACHYTE PORPHYRY DIKES. Cutting major syenite intrusive centers of Little Rocky Mountains (see Map Symbols).

Tla LAMPROPHYRE DIKES OR SMALL PLUGS. Occur in foothills of Little Rocky Mountains.

Tsyp SYENITE PORPHYRY (?MIDDLE EOCENE) — Forms main intrusive centers of main Little Rocky Mountains and several small domes on the south and east flanks of the mountains. Also occurs as dikes (see Map Symbols) locally cutting the massive syenite porphyry intrusives in Little Rocky Mountains.

Tial ALKALIC INTRUSIVE DIKES, UNDIVIDED (?MIDDLE EOCENE) — Medium-brown-weathering, coarsely crystalline; weathers to crumbly, coarse rubble. One dike mapped near western border of map; similar to those mapped on adjacent Winifred quadrangle (Wilde and Porter, 2001); composition not studied (see Map Symbols).

CRETACEOUS

UPPER CRETACEOUS

Khc HELL CREEK FORMATION — (from Knechtel, 1959) Formation exposed only in small outcrops above Fox Hills Sandstone in southeast corner of quadrangle. Interbedded gray to light-brown sandstone with brown sandstone concretions, and white to light-colored to drab siltstone, claystone and shale locally calcareous with abundant small calcareous concretions; brownish gray carbonaceous bentonitic claystone also interbedded; persistent beds of carbonaceous shale and lenticular coal near base of formation locally mined. Rare fossil plants and vertebrates indicate latest Cretaceous age. Only lower beds exposed; thickness of 400 to 500 ft reported by Hearn, Jr. (1976) in Bears Paw Mountains to west.

Kfh FOX HILLS FORMATION — (from Knechtel, 1959) Formation present only in limited outcrops in southeast corner of quadrangle. Light-yellowish gray, thin-bedded to massive sandstone, commonly concretionary; minor interbeds of brown and gray siltstone and shale. Thickness of 60 to 100 ft reported by Hearn, Jr. (1976) in Bears Paw Mountains to west.

Kb BEARPAW SHALE — (from Knechtel, 1959) Medium-gray, fissile shale weathering steel-gray or rarely brownish gray; underlies low, sage-covered, gently rolling topography across most of map area; forms a characteristic gumbo soil; thin white bentonite layers common throughout. Large ovoid dark-reddish purple-weathering concretions common, especially in lower part; gray weathering, calcareous concretions more common. Selenite crystals commonly scattered on exposed surfaces. Knechtel reports many thin beds and lenses of cherty material. Base, where exposed, comprised of bentonite and gypsiferous clayey shale. Unit forms the high bluffs and broken topography known as the “Missouri Breaks” along the Missouri River. Top of unit eroded off in map area; thickness not measured in Zortman quadrangle; a thickness of 1,318 ft was measured by Cobban (1953, p. 101) about 75 miles to the southeast in the Mosby area.

Kjr JUDITH RIVER FORMATION — (from Knechtel, 1959) Light-colored interbedded sandstone, siltstone, sandy mudstone, claystone, and shale. Sandstones sometimes soft, but commonly well cemented, forming dark-brown resistant ledges; quartzose and generally fine-grained; commonly cross-stratified, locally massive, and in laterally discontinuous beds enclosed in mudstone; rusty-brown to purplish black-weathering ironstone concretions locally abundant. Light-colored, bentonitic mudstones and thin, dark-brown, carbonaceous shales and coaly lenses give banded appearance to upper part of unit where exposed in western map area; badlands topography is developed on upper part of unit where exposures are extensive. Unit forms cliffs and ridges encircling the Little Rocky Mountains and low, resistant ridges of faulted folds where it is best exposed in the western map area. Thickness averages about 380 ft (Knechtel, 1959, p. 744).

Kcl CLAGGETT SHALE — Dark-gray or grayish brown on fresh surfaces, commonly weathered to characteristic soft brown; blocky to fissile, commonly sandy in upper part. Characteristic orange-weathering, smooth, ovoid, calcareous concretions with yellow calcite vein filling in middle and upper part of unit, commonly highly fractured and weathered into mounds of small, sharp-edged orange-brown fragments. Numerous grayish white bentonite layers in lower 25 ft of unit forming thick gray to yellowish interval where exposed. A horizon of black chert pebbles embedded in dark shale forms the contact with the underlying Eagle Sandstone. Commonly bare to sparsely vegetated. Thickness given by Knechtel (1959, p. 744) as about 500 ft.

Ke EAGLE SANDSTONE — (from Knechtel, 1959) Composed of a lower cross-stratified, fine-grained, light-yellow to buff-weathering sandstone unit locally called the Virgelle following usage of that term farther west, and an upper unit of light-gray sandy shale, siltstone, and thin sandstone beds. A thin interval of 1/4-inch to 1.5-inch diameter chert pebbles, predominantly black but also green, brown, and red, occurs on upper surface at contact with overlying Claggett Shale; pebbles commonly occur vertically mixed through lower few feet of Claggett, presumably redistributed by burrowing organisms. Lower sandstone forms prominent ridges on western flanks of Little Rocky Mountains but forms poor outcrops on eastern flanks owing to a regional decrease in sand content eastward. Thickness given by Knechtel (1959, p. 742) as 223 to 260 ft in Little Rocky Mountains.

Ktc TELEGRAPH CREEK FORMATION — Medium- to light-gray weathering, noncalcareous, interbedded siltstone and fissile gray shale, sandier in upper part. Upper contact transitional, generally placed at base of lowest cliff-forming sandstone of overlying Eagle Formation. Approximate thickness 200 ft (based on descriptions by Knechtel, 1959, p. 742).

Ktcb TELEGRAPH CREEK FORMATION THROUGH BELLE FOURCHE FORMATION, UNDIVIDED. Includes, in descending order, the Telegraph Creek and Niobrara Formations, Carlile Shale, Greenhorn Formation, and Belle Fourche Shale; on small domes on southeastern and southern flanks of Little Rocky Mountains where outcrops are poor on steep timbered slopes. Formations described in following text.

Ktca TELEGRAPH CREEK FORMATION THROUGH CARLILE SHALE , UNDIVIDED. Knechtel's (1959) Upper Warm Creek Shale. Includes, in descending order, the Telegraph Creek and Niobrara Formations and Carlile Shale where underlying Greenhorn Formation and Belle Fourche Shale are mapped. Formations all poorly exposed, but occasional small exposures of typical lithologies confirm their presence in the foothills around the mountains. Thickness approximately 830 ft (Knechtel, 1959, p.742)

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Kn **Niobrara Formation** (cross section only) — Dark- to medium-olive-gray, fissile shale containing numerous thin bentonite beds; weathers medium-gray in lower part and characteristically yellowish orange in calcareous upper part which is stratigraphically equivalent to "first white specks zone" of subsurface terminology.

Kca **Carlile Shale** (cross section only) — Dark-gray to medium-gray-weathering, noncalcareous shale with three characteristic concretion horizons. Lower part: horizons of oval, dark red, ironstone concretions that weather to small, angular, chippy fragments forming red, rubbly patches in blue-gray fissile shale. Middle part: zone of large, sandy, dull-orange-weathering concretions, commonly highly fractured and containing cone-in-cone structures. Upper part: white-gray-weathering concretions.

Kgrm GREENHORN FORMATION AND MOSBY SANDSTONE MEMBER OF BELLE FOURCHE SHALE. Mapped as a single thin unit; outcrop trace of unit indicated by dashed line pattern labeled with "Kgrm". Approximate thickness of 70 ft given by Knechtel (1959, p. 742) for combined Greenhorn Formation and Mosby Sandstone Member of Belle Fourche.

Greenhorn Formation — Medium- to light-gray, strongly calcareous shale weathering to characteristic cream-colored, calcareous soil in occasional small patchy exposures across grassy surfaces.

Mosby Sandstone Member of Belle Fourche Shale — Brown-weathering, light-gray, very fine-grained to fine-grained sandstone, locally highly calcareous, commonly fossiliferous including lenses of coquina dominated by snail forms; occasionally contains small black chert pebbles. Occurs in thin, commonly cross-stratified, slabby beds with interbeds of dark-gray shale; transitional above lower Belle Fourche shales. Unit commonly concretionary, forming low irregular ledge across grassy surfaces. Two thin, concretionary, occasionally fossiliferous, sandstone horizons observed.

Kbfl LOWER MEMBER, INFORMAL, OF BELLE FOURCHE SHALE. Lower Member of Warm Creek Shale of Knechtel (1959; p. 741). Mapped where overlying Mosby Sandstone Member of Belle Fourche Shale and Greenhorn Formation are mapped together on east side of Little Rocky Mountains. Dark gray, noncalcareous, clayey shale, weathering light-bluish gray; dark purpleish black ironstone concretions and associated bentonites and bentonitic shale in lower part; thin bed of gray, coarse- to medium-grained, chert-pebbly sandstone occasionally observed about 100 ft above base of member; prominent large, orange-weathering, calcareous, septarian concretions in upper part. Unit generally poorly exposed. Thicknesses of 155 and 248 ft reported by Knechtel (1959, p. 741).

Km MOWRY SHALE — Dark- to medium-gray, interbedded thin beds and laminae of dark-gray clayey shale, siltstone, and very fine-grained sandstone weathering a characteristic light-silvery gray; siliceous throughout. Fish scales and small fish bone fragments common on many bedding plane surfaces. Upper part of formation contains more siltstone and sandstone and commonly forms light silvery-blue to white bare patches across slopes. Knechtel (1959, p. 740) reports thicknesses of 62 to 90 ft.

LOWER CRETACEOUS

Ktf THERMOPOLIS FORMATION AND FALL RIVER SANDSTONE, UNDIVIDED — Thermopolis Formation members include, in descending order, the Shell Creek Shale, Cyprian (?Muddy) Sandstone on southwest flank of Little Rockies, and Skull Creek Shale overlying the Fall River Sandstone.

Thermopolis Shale — Composed of dark-gray to black shale, with a medial, fine-grained sandstone; numerous thin bentonite beds throughout. Generally valley-forming and poorly exposed throughout map area. Three members recognized but not mapped separately; in descending order: Shell Creek Shale Member: dark-bluish gray-weathering, soft, fissile, clayey shale; Cyprian Sandstone Member: 27 ft of gray to tannish gray-weathering, fine-grained sandstone coarsening upward to coarse-grained in upper part of upper cross-stratified sandstone; chert-pebble conglomerate at top of unit; pebbles mostly black but some are green, brown and gray; lower part of unit thinner-bedded and interbedded with gray, clayey shale (see Porter and others, 1997); Skull Creek Member: very dark, fissile, unresistant shale; lower part contains numerous thin, iron-stained siltstone and very fine-grained sandstone laminae that are “Dakota silt” of subsurface; Total thickness of 565 ft to 600 ft (Knechtel, 1959, p. 739).

Fall River Sandstone — Tannish brown-weathering, light-grayish tan or buff-tan, predominantly fine-grained, quartzose sandstone, commonly brown-speckled on fresh surfaces (First Cat Creek sandstone of subsurface). Cross-stratified and ripple-laminated in thin to thick beds with numerous very thin, dark shale partings. Interbedded dark, clayey to sandy shale. Invertebrate tracks and trails on bedding plane surfaces. Base of unit is sandstone resting on Kootenai Formation red beds. Unit only occasionally exposed; generally recognized by float slabs of tan, rippled, quartzose sandstone. Knechtel (1959) reports a thickness of 97 ft, but his description suggests this thickness includes an upper 72 ft that commonly are assigned to the “Dakota silt” of the basal Skull Creek Shale elsewhere

Kk KOOTENAI FORMATION — Dark- to medium-red, grayish green, and minor .buff-colored silty, blocky-weathering shale, and fine- to coarse-grained, chert-bearing, feldspathic, commonly cross-stratified sandstone. Thick basal sandstone (Third Cat Creek sandstone of subsurface) is gray, medium- and coarse-grained, conglomeratic, chert-bearing, cross-stratified; top of unit is dense, light-gray, brown-weathering limestone containing fresh-water flora; about 60 ft thick. Upper part of formation dominated by variegated mudstones, predominantly red and yellowish tan, and brown, thin-bedded, fine-grained, quartzose sandstones with minor chert and feldspar (Second Cat Creek sandstone of subsurface). Formation forms small brown ledges and pinkish soils. Thicknesses of 147 to 159 ft reported by Knechtel (1959, p.737).

JURASSIC

Js SEDIMENTARY ROCKS, UNDIVIDED — Includes the **Morrison Formation** (Upper Jurassic; thickness 60 ft) composed predominantly of light-gray, noncalcareous mudstones with a few thin, brown-weathering, fine-grained, quartzose sandstones and an upper few ft of carbonaceous shale with abundant plant remains; underlain by the Middle Jurassic **Ellis Group** (230 to 330 ft thick) represented by the **Swift Sandstone,** composed of a lower gray marine shale (approx. 100 ft thick) containing large brown, ferruginous concretions, a persistent basal 2-inch fossiliferous pebble layer, and abundant belemnites and overlain by fine-grained, glauconitic, calcareous sandstone; and by the underlying **Rierdon Formation,** a gray marly limestone weathering light-gray and locally highly fossiliferous, dominated by *Gryphea* sp., and *Belemnites* sp. (Knechtel, 1959, p. 736-737).

MISSISSIPPIAN

Mm MADISON GROUP, UNDIVIDED (LOWER MISSISSIPPIAN). Includes the **Mission Canyon Limestone**, a light-gray, massive limestone, weathering whitish gray, containing numerous solution cavities ranging from vugs to caverns and forming massive white timbered cliffs, underlain by the **Lodgepole Limestone**, a thin-bedded, dark- to light-gray, fossiliferous, cliff-forming limestone with common dark-gray chert. Total thickness of 900 ft to 1,100 ft (Knechtel, 1959, p. 732-735).

MISSISSIPPIAN AND DEVONIAN

MDs MISSISSIPPIAN AND DEVONIAN SEDIMENTARY ROCKS, UNDIVIDED. Includes the **Three Forks Shale** (approx. 40 to 85 ft) composed primarily of light-gray and light-green calcareous claystone, shale, and siltstone, locally sandy; underlain by the **Jefferson Formation** (approx. 400 to 500 ft thick) composed primarily of dark gray limestone that may weather chocolate-brown or light-gray, is generally massive with bedding preserved in lower part, and has fetid odor locally; underlain by the **Maywood Formation** (approx. 175 ft thick) composed of variegated tan, brown, yellow, red, and green beds of calcareous shale, siltstone, and impure limestone and dolomite; upper part mostly bright red calcareous shale (Knechtel, 1959, p. 730-732).

ORDOVICIAN

Ob BIGHORN DOLOMITE (UPPER ORDOVICIAN) — Light-colored, gray, massive, dolomitic limestone and dolomite; dappled, irregular weathering surface derives from differential weathering of small (approx. 1 in. diam.), closely spaced, irregularly shaped, dark-gray dolomite masses within less resistant, lighter-gray dolomite. Thicknesses ranging from 275 ft to 57 ft indicate an erosional upper contact (Knechtel, 1959, p. 728-729).

ORDOVICIAN AND CAMBRIAN

OCs ORDOVICIAN AND CAMBRIAN SEDIMENTARY ROCKS, UNDIVIDED — Includes the **Emerson Formation** (Knechtel, 1956) of Middle and Late Cambrian and probable Early Ordovician age, composed of greenish gray and gray shale interbedded with thin limestones, dolomites that increase in number upward and intraformational edgewise conglomerates; underlain by the Middle Cambrian **Flathead Sandstone** composed of light-gray, greenish or tan quartzose sandstone with occasional intraformational pebble conglomerate and minor shale. Thickness of Emerson estimated be between 950 ft and 1,100 ft though all observed sections are incomplete; thickness of Flathead Sandstone probably not more than 50 ft (Knechtel, 1959, p. 727).

PRECAMBRIAN PRE-BELT

pCm PRECAMBRIAN PRE-BELT METASEDIMENTARY AND METAVOLCANIC ROCKS, UNDIVIDED — Includes biotite schists and gneisses interbedded with quartzites bearing rounded quartz grains, and presumed synchronous extrusive volcanic rocks represented by hornblende gneisses and amphibolites (Knechtel, 1959, p. 724-725).

MAP SYMBOLS

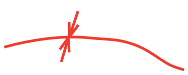
Contact: dashed where approximately located; dotted where concealed; queried where uncertain

Trace of thin mapped unit; letter symbol indicates stratigraphic unit

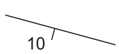
Fault: arrows indicate relative horizontal movement

Fault: dashed where approximate; dotted where concealed; ball and bar on down-thrown side

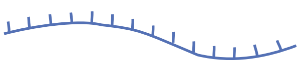
Anticlinal fold showing trace of axial plane



Synclinal fold showing trace of axial plane

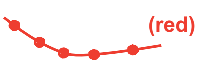


Strike and dip of bedding; degree of dip indicated



Southern limit of continental glaciation; hachures on ice side

Trachyte porphyry dike in Little Rocky Mountains



Aegerine trachyte porphyry dike in Little Rocky Mountains

Syenite porphyry dike in Little Rocky Mountains

Alkalic igneous dike or plug; specific composition unknown; located in western map area beyond Little Rocky Mountains

SOURCES OF PREVIOUS GEOLOGIC MAPPING IN QUADRANGLE

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