GEOLOGIC MAP OF THE WINIFRED 30' x 60' QUADRANGLE

CENTRAL MONTANA

Compiled and Mapped

by

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SUMMARY

Structural and Stratigraphic Setting

The Winifred quadrangle is located in central Montana (figure 1). It includes the southern part of the Bears Paw Mountains and a large area to the south that is bisected by the east-flowing Missouri River. This broad area both north and south of the river is dominated by relatively shallow faults that apparently originated from the gravity-slide movement of very large fold- and fault-bounded blocks off the Bears Paw Mountains (Reeves, 1924; Hearn, Jr., 1976). Strata involved in gravity-slide displacement have formed steep-sided asymmetric anticlinal folds that commonly are broken by steep compressional faults. Many of these faults subsequently underwent back-sliding of the hanging wall under tension. Gravity-slide-faults and folds encircle the Bears Paw Mountain uplift at distances as much as 30 or more miles away from the mountain front. Surface and subsurface data (Hearn, Jr., 1976) indicate that thick shale in the Upper Cretaceous sedimentary section, particularly within the Carlile Formation, is the principal interval within which the bedrock failure has occurred; older strata appear essentially unfaulted.

According to Hearn (1976), the timing of this gravity sliding apparently was closely associated with the late early Eocene and middle Eocene uplift of the Bearpaw Arch and with the synchronous widespread deposition of very thick volcanic flows and pyroclastics (as much as 6,000 ft thick - Hearn, Jr., 1976; Marvin and others, 1980). The greatly overweighted sedimentary layers failed, causing large blocks of strata and volcanics to be transported down-slope onto the surrounding plains. These detached blocks left graben structures along the margins of the central Bearpaw Arch into which the volcanic fields collapsed and have been preserved, while volcanic rocks on slabs carried onto the plains have been eroded away. A variety of intrusive rocks, also emplaced during this middle Eocene time, have been preserved in the central arch graben area and on the arch flanks as well as in the adjacent plains. Both the intrusive and volcanic rocks of the Bears Paw region are associated with the middle Eocene phase of intrusion and volcanism in the Central Montana Alkalic Province.

Figure 2 provides a correlation of units mapped in the quadrangle. Within the southern Bears Paw Mountains, intrusive and extrusive rocks are commonly fault-bounded against each other and against Upper Cretaceous and Tertiary sedimentary rocks. On the southern flanks of the mountains a thick Upper Cretaceous section is exposed that flattens to an essentially horizontal orientation south of the mountains except where these beds are involved in faulting along the leading edges or lateral margins of gravity-slide fault blocks. In the Winifred quadrangle area the exposed bedrock involved in these faults includes, in ascending order, the Telegraph Creek, Eagle, Claggett, Judith River, and Bearpaw Formations. Shale below the Telegraph Creek Formation crops out in only one small area along Arrow Creek in the southwest part of the quadrangle where it is designated as the Kevin Member of the Marias River Formation. This designation follows the work of Cobban (1976) for Upper Cretaceous marine rocks below the Telegraph Creek in the Great Falls area. It also follows the mapping in the south-adjacent Lewistown quadrangle by Porter and Wilde (1993; revised 1999) where the west side of the Judith Mountains was chosen as the transition area for the terminology of the eastern and western Cretaceous sedimentary basin facies. In the eastern part of the Winifred quadrangle, however, shale units below the Telegraph Creek Formation, known only in the subsurface (see Cross Section A-A'), are assigned to the Niobrara and Carlile Formations in

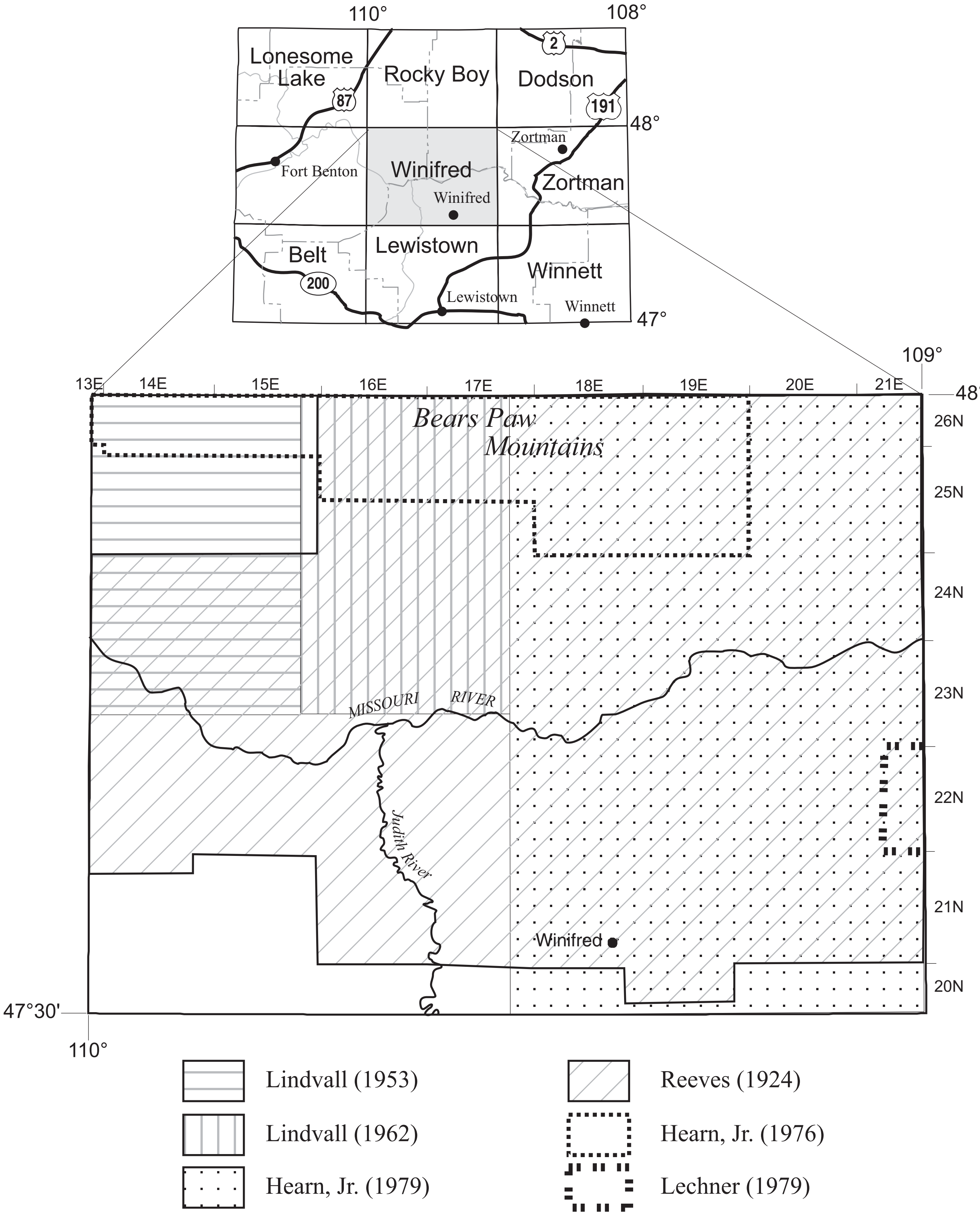

Figure 1. Location map for Winifred quadrangle showing areas covered by earlier geologic maps within the quadrangle (see Sources of Previous Geologic Mapping), and location of adjacent geologic maps published by MBMG.

keeping with the similarity of the units to the eastern sedimentary basin facies.

Landslide deposits are extensively developed within the Claggett Formation where often most or all of the outcrop is slumped and contorted. These massive landslides, not separately mapped, are readily recognized across the slopes beneath broad benches developed on the Judith River Formation such as Eightmile and Evers Benches in the northwest part of the map area.

Glacial deposits of several different origins occur but are not extensive nor thick across the map area. They have generally not been mapped. A hachured blue line on the map indicates the extent of continental glaciation across the quadrangle area.

This report combines the mapping of Reeves (1924), Lindvall (1953; 1962), and Hearn, Jr. (1976; 1979) within the quadrangle with new mapping by the authors. Mapped units have been integrated with recent work completed by MBMG in adjacent 1:100,000-scale quadrangles (figure 1).

Cross Section A-A'

Cross section A-A' crosses a number of folds and faulted folds in the southeast 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, 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 (the Kn + Kca unit on the cross section; the Niobrara is approximately stratigraphically equivalent to the Kevin Member mapped at the surface in the southwest map area). In this compressional regime, strata within a slide block were commonly folded, and apparently asymmetric folds frequently failed, forming shallow thrust faults.

The planes of these thrust faults dip back toward the mountain front, in this case northward. The dips of fault planes intersected along cross section A-A' are conjectural only; no data have been reported by us or by previous authors. However, faults exposed along the Missouri River appear to dip as much as 40 degrees or more. Many of the observed faults in the region now express a normal-fault relationship that presumably reflects a relaxation of the compressional stress (see cross section A-A'). This relaxation allowed many hanging-wall fault blocks to slide back along the fault plane. In the east-adjacent Zortman quadrangle area (Porter and Wilde, 2001), most of the faults intersected along cross section A-A' have retained their compressional geometry.

Similarly, around the entire Bears Paw Mountains, the horizontal displacement created by the plainsward translation of huge gravity-slide blocks apparently has been accommodated by (1) "wrinkling" of broad areas into long, subparallel folds, and (2) northward extensional backsliding of the hanging-walls of many faults when the compressional stress field relaxed. Within a discrete gravity-slide block, these two features are intermixed with the reverse faults that that reflect the original compressional regime. Another possible mechanism for accommodating the horizontal displacement would be the up-ramping of strata over a stable block at the distal edge of the slide block, in the manner of a landslide. No such deformation is recognized at the distal edge of the gravity slide features in this map area. Possibly this deformation occurs within the ductile Bearpaw Shale and is not readily observed beneath the clayey soil and cover.

The gradient of the glide planes beneath the gravity slide blocks has been investigated based on drill hole data (Hearn,1976): 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. 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.

ACKNOWLEDGMENTS

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Correlation Chart of Map Units
Winifred 30' x 60' Quadrangle

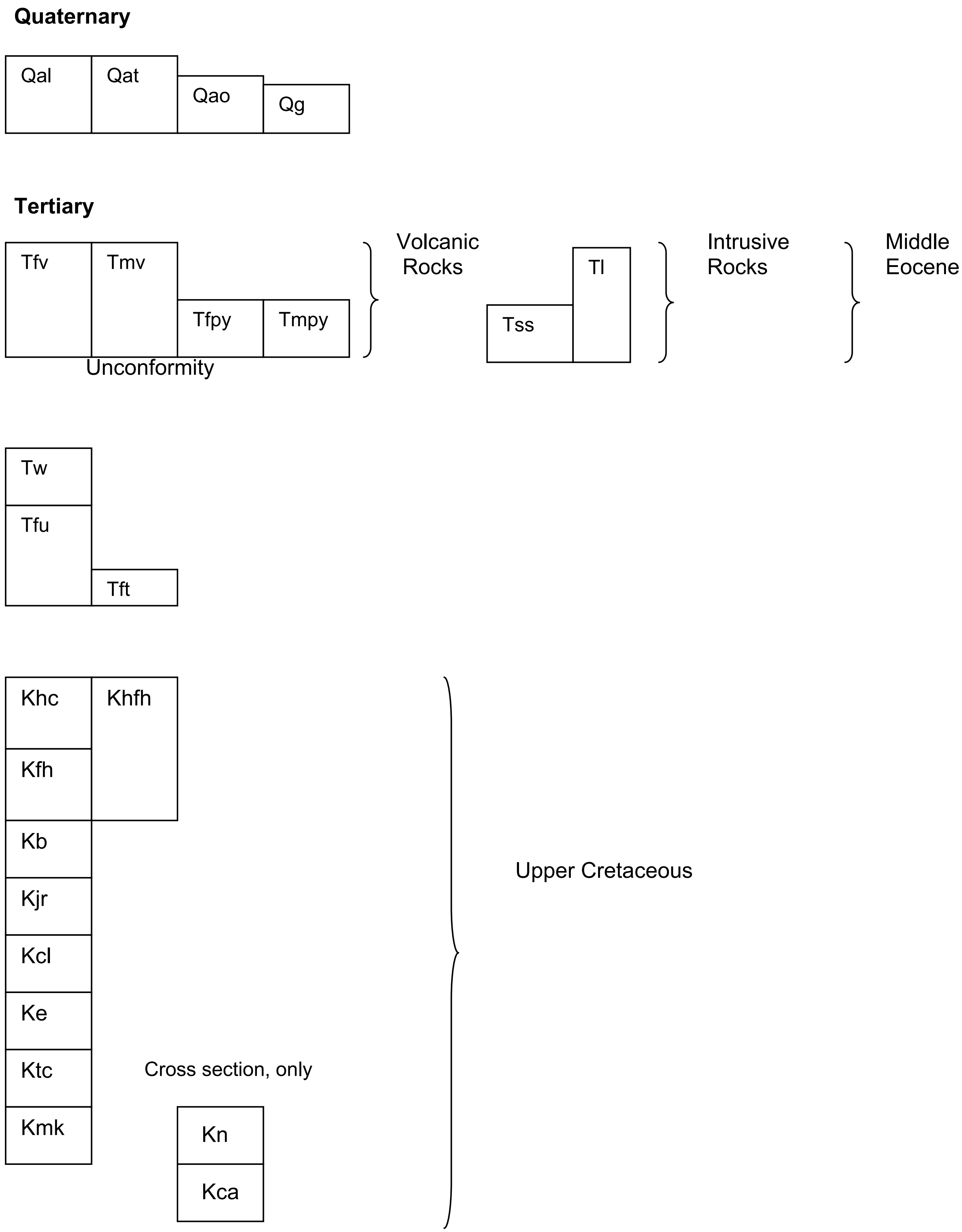


Figure 2. Correlation Chart of map units.

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, where terrace deposits not mapped separately. Thickness not measured.

Qat ALLUVIAL TERRACE DEPOSITS (HOLOCENE) — Yellowish tan and grayish tan-weathering, unconsolidated clay, silt, sand, and some pebbles, generally well stratified; occurring on flat benches at slightly higher elevations than modern flood plain, and dissected by modern drainages; generally soil covered. 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; unit occurs along modern drainages, generally slightly above modern alluvial flood plains; includes some terrace deposits not mapped separately, and deposits of glacial material presently being reworked by modern processes; poorly exposed except where cut by streams. Thickness not measured.

Qg GLACIAL DEPOSITS, UNDIVIDED (PLEISTOCENE) — Light-colored sand, silt, and clay, including poorly sorted till with common cobble fraction and well sorted lake-bed(?) deposits. Thickness not measured.

TERTIARY

Volcanic rocks (Middle Eocene)

Tfv FELSIC VOLCANIC ROCKS — (modified from Hearn, Jr., 1976) Flows and flow breccias of porphyritic latite and quartz latite; light-gray, gray and brown; phenocrysts of potassium feldspar, plagioclase, augite, hornblende, and biotite; interlayered with felsic and mafic pyroclastic rocks and mafic flows; extrusive equivalent of intrusive porphyritic latite. Maximum thickness about 5,000 ft.

Tfpy FELSIC PYROCLASTIC ROCKS — (modified from Hearn, Jr., 1976) Agglomerate, tuff-breccia, lapilli tuff, tuff, water-laid volcanic sediments, and coarse mudflow deposits; contain more than 50 percent fragments of felsic volcanic rocks; inclusions of biotite pyroxenite and Precambrian basement rocks locally abundant; commonly form lowermost volcanic unit; in part deposited in local early collapse basins; fossil plants and fish indicate middle Eocene age. Maximum thickness about 3,000 ft.

Tmv MAFIC VOLCANIC ROCKS — (modified from Hearn, Jr., 1976) Flows and flow breccias of phonolite and mafic phonolite; brown, red, and purple; phenocrysts of olivine, augite, biotite, analcime, and rare leucite; interlayered with felsic flows and felsic and mafic pyroclastic rocks; extrusive equivalent of shonkinite and syenite. Maximum thickness about 5,000 ft.

Tmpy MAFIC PYROCLASTIC ROCKS — (modified from Hearn, Jr., 1976) Agglomerate, tuff-breccia, lapilli tuff, tuff, water-laid volcanic sediments and mudflow deposits; contain more than 50 percent fragments of mafic volcanic rocks; inclusions of biotite pyroxenite and Precambrian rocks locally abundant; commonly form lowermost volcanic unit; in part deposited in local early collapse basins; fossil plants and fish indicate middle Eocene age. Maximum thickness about 3,000 ft.

Intrusive rocks (Middle Eocene)

Tl PORPHYRITIC LATITE — (modified from Hearn, Jr., 1976) Dikes, sill, lacoliths and stocks; light-gray to brown; fine-grained felsic porphyritic rocks; most contain less than 20 percent mafic minerals; phenocrysts of augite ubiquitous; may represent several episodes of intrusion, and post-date most but not all shonkinite-syenite intrusions.

Tss SHONKINITE AND SYENITE — (modified from Hearn, Jr., 1976) Dikes, sills, laccoliths, plugs, and stocks; fine- to coarse-grained, porphyritic to equigranular; mafic mineral content of shonkinite more than 40 percent, mafic syenite 20 to 40 percent, and syenite less that 20 percent; many varieties weather to biotite-rich soils with no outcrop; represent several episodes of intrusion, and are the earliest intrusive rocks in the eastern Bears Paw Mountains.

Tial INTRUSIVE ROCKS, ALKALIC, UNDIVIDED (see Map Symbols) — Medium-brown-weathering, coarsely crystalline; commonly weathers to crumbly, coarse rubble.

Sedimentary rocks

Tw WASATCH FORMATION (LOWER EOCENE) — (modified from Hearn, Jr., 1976) Variegated red, pink, lavender, light-green, yellowish gray, and white shale, bentonitic claystone, and siltstone; interbedded sandstones light-gray, brown and green, fine- to coarse-grained, cross-bedded, with lenses of boulder conglomerate in upper part of formation containing clasts derived from mountain uplifts to the west or southwest including argillite and quartzite from Proterozic Belt Supergroup rocks, porphyritic igneous rocks, and limestone and dolomite; clasts locally crushed, fractured, and recemented. Nonmarine; fossil plants and vertebrates indicate early Eocene age. Top of formation missing due to pre-volcanic erosion or tectonic disruption or both. Maximum measured thickness 800 ft.

Tfu FORT UNION FORMATION, UNDIVIDED (PALEOCENE) — (modified from Hearn, Jr., 1976) Light-brown to light-yellow, thin- to thick-bedded sandstone with brown sandstone concretions; interbedded with light-colored to greenish siltstone, claystone and shale; locally contains carbonaceous shale and coal locally mined. Nonmarine; fossil plants and vertebrates indicate early Paleocene age. Maximum thickness about 1,300 ft.

Tft TULLOCK MEMBER OF FORT UNION FORMATION —

UPPER CRETACEOUS

Khc HELL CREEK FORMATION — (modified from Hearn, Jr., 1976) 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. Thickness 400 to 500 ft.

Kfh FOX HILLS FORMATION — (modified from Hearn, Jr., 1976) Light-yellowish gray, light-brown, and yellow, thin-bedded to massive sandstone, commonly concretionary; minor interbeds of brown and gray siltstone and shale. Thickness 60 to 100 ft.

Khfh HELL CREEK AND FOX HILLS FORMATIONS, UNDIVIDED

Kb BEARPAW SHALE — Medium-gray, fissile shale weathering to steel-gray or rarely brownish gray, underlying low, sage-covered, gently rolling topography. Thin, greenish white bentonite layers common throughout and cause a characteristic gumbo soil. Base, where exposed, comprised of bentonite and gypsiferous clayey shale. Uppermost beds of formation silty and sandy in transition with overlying Fox Hills Formation. Large (as much as 1 ft diameter) ovoid, dark-reddish purple-weathering concretions common in lower part; gray-weathering, oval, calcareous concretions more common in upper part; both concretion types commonly very fossiliferous. Estimated thickness of 900 ft is given by Reeves (1924), although tectonic thinning and fault-repeated section are likely within the large fault blocks produced by gravity sliding. Formation thinned by erosion westward across map area, and is completely removed in western map area.

Kjr JUDITH RIVER FORMATION — Composed of three distinct intervals. *Lower sandstone unit:* light-yellowish gray-weathering, locally orange-stained, very fine- or fine-grained, quartzose, massive to poorly bedded, burrowed to bioturbated; uppermost beds light-brown, ferruginous, forms resistant ledges; Parkman Sandstone of subsurface usage. *Middle unit:* greenish gray-weathering, fine-grained sandstones, siltstones, mudstones, and brown carbonaceous shale typically with conspicuous banded appearance; numerous conspicuous rusty-brown to purplish black-weathering ironstone concretions; many beds bentonitic. *Upper unit*: composed of basal yellowish gray to yellowish brown-weathering fine-grained, quartzose sandstone overlain by sequence of interbedded sandstones, mudstones, and carbonaceous shale with common small ferruginous concretions; sandstones light-colored, cross-stratified, commonly discontinuous laterally, and have dark-brown ferruginous caps; top of unit locally contains a thin, dark, fissile, oyster-bearing shale overlain by Bearpaw Shale. Middle and upper units of formation typically form barren slopes and badlands topography. Thickness is approximately 500 feet in the map area (Reeves, 1924).

Kcl CLAGGETT SHALE — Dark-gray or grayish brown on fresh surfaces, commonly weathered to soft brown; blocky to fissile. Characteristic dull-orange-weathering, smooth, ovoid, calcareous concretions in middle and upper part of unit; concretions commonly contain yellow calcite vein filling and are commonly highly fractured, forming mounds of small, sharp-edged orange-brown fragments. Numerous grayish white bentonite layers (1 to 5 inches thick) in lower part of unit; base composed of thick bentonitic interval in which three white, slightly swelling bentonites are sometimes distinguishable. Upper part contains laterally persistent sandstone beds forming transitional base with overlying Judith River Formation. Exposed surfaces commonly bare to sparsely vegetated. Average thickness is approximately 550 ft (Reeves, 1924), but varies; thickness variations, particularly in the gravity-fault block structures, are likely caused by tectonic squeezing and/or fault repetition. Formation commonly is extensively disrupted by massive landslides not separately mapped, particularly across slopes of benches developed on the overlying Judith River Formation.

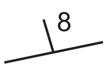
Ke EAGLE SANDSTONE — Composed of three distinct units. *Lower unit (Virgelle Member):* generally white-weathering, locally concretionary, fine- and medium-grained, friable to moderately hard, salt-and-pepper sandstone, generally massive and burrowed to locally cross-stratified; forms prominent cliff above underlying Telegraph Creek Formation; about 30 ft thick; commonly milky-white but occasionally yellowish brown and locally stained reddish. *Middle unit:* poorly exposed, thin sandstones and grayish green shale with thin, discontinuous lignite seams and some bentonitic intervals. *Upper unit:* yellowish tan-weathering, light-gray, fine-grained, salt-and-pepper sandstone, commonly cross-stratified, massive, cliff-forming, with thin to 2-ft-thick interval of black pebbles (from granule to 2 inches in diameter) at top of sandstone or in dark shale slightly above top of unit in lowest Claggett beds. Thickness of formation approximately 250 to 300 ft.

Ktc TELEGRAPH CREEK FORMATION — Medium- to light-gray-weathering, interbedded, noncalcareous sandstone, siltstone, and fissile shale, sandier in upper part. Upper contact transitional, generally placed at base of lowest cliff-forming sandstone of overlying Eagle Formation. Only upper part exposed except along southwest border of map area. Estimated thickness 100-200 ft (Reeves, 1924).

Kmk KEVIN MEMBER OF MARIAS RIVER FORMATION — Dark-gray-weathering, fissile, slightly calcareous shale. Uppermost beds exposed along Arrow Creek in southwest map area. Unit stratigraphically equivalent to Niobrara Formation in subsurface in eastern map area.

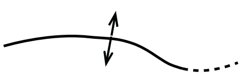
MAP SYMBOLS


Contact; dotted where concealed

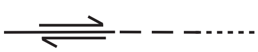


Strike and dip of bedding; degree of dip indicated


Anticlinal fold shown by trace of axial plane; dotted where concealed. Arrow indicates direction of plunge where known.


Synclinal fold shown by trace of axial plane; dotted where concealed. Arrow indicates direction of plunge where known.


Fault; dashed where inferred, dotted where concealed; ball and bar on downthrown side


Fault; dashed where inferred, dotted where concealed; arrows indicate apparent relative horizontal movement


Approximate limit of undifferentiated glacial deposits; hachures on side of glacial ice (blue line on map)


Igneous dikes, sills, and small plugs (red on map)

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