

Montana Bureau of Mines and Geology

GEOLOGIC MAP OF THE WINNETT 30' x 60' QUADRANGLE
CENTRAL MONTANA

by

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GEOLOGIC SUMMARY

The Winnett 30'x60' quadrangle of central Montana is approximately equally divided between the geologic settings of the central Montana uplift and the Blood Creek Basin. Geologic structure, stratigraphy, and geologic history are highly contrasted between these two settings: the central Montana uplift is a large, west-east structural block that has dominated central Montana since Proterozoic time; the Blood Creek Basin to the north is a broad, generally featureless structure with a poorly defined and unmapped surface axial trace. The boundary between these two settings is the steeply dipping north limb of the asymmetric, northwest-southeast-trending Cat Creek Anticline. Along this anticline 10 domes are recognized, 6 in the Winnett quadrangle, and 3 have produced oil from Lower Cretaceous and Jurassic rocks. The Cat Creek Anticline is terminated on the west by the Judith Mountains whose easternmost exposed pluton, Black Butte, occupies the northwest corner of the map.

Bedrock exposures (figure 1) in the area are predominantly marine and nonmarine sedimentary rocks of Lower and Upper Cretaceous age. Paleozoic rocks are poorly exposed in a narrow band on the steep flanks of Black Butte. Paleocene Fort Union Formation beds are preserved in a few small erosional remnants in the Blood Creek Basin, and Paleocene-Eocene ultramafic intrusions occur as northeast-trending dikes and small plugs, predominantly in the southwest area of the map. Quaternary deposits include, in addition to modern stream alluvium and colluvium, continuous deposits of older alluvium, including terrace deposits, occurring along and slightly higher than present stream courses in the northern part of the map area. Limited pediment gravels remain on the flanks of the Judith Mountains.

Previous mapping was conducted by Reeves (1927), Johnson and Smith (1964), and Nelson (1993) in the eastern part of the Winnett quadrangle, along the eastern end of the Cat Creek anticline. Mapping of the Judith Mountains (Black Butte) in the northwestern part of the quadrangle was conducted by Goddard (1988). No earlier mapping was available for the Blood Creek basin beyond the work of Ross and others (1955). The effort of Johnson and Smith (1964) to follow Cobban (1951, 1953a) in applying Black Hills stratigraphic terminology to the central Montana marine Cretaceous section has been continued in the Winnett quadrangle, permitting more detailed mapping of the formerly mapped Colorado Shale that included the Fall River Sandstone through the Niobrara Formation. This new mapping has revealed a number of small folds on the broad south limb of the Cat Creek Anticline and a new small dome, South Fork dome, in the western map area.

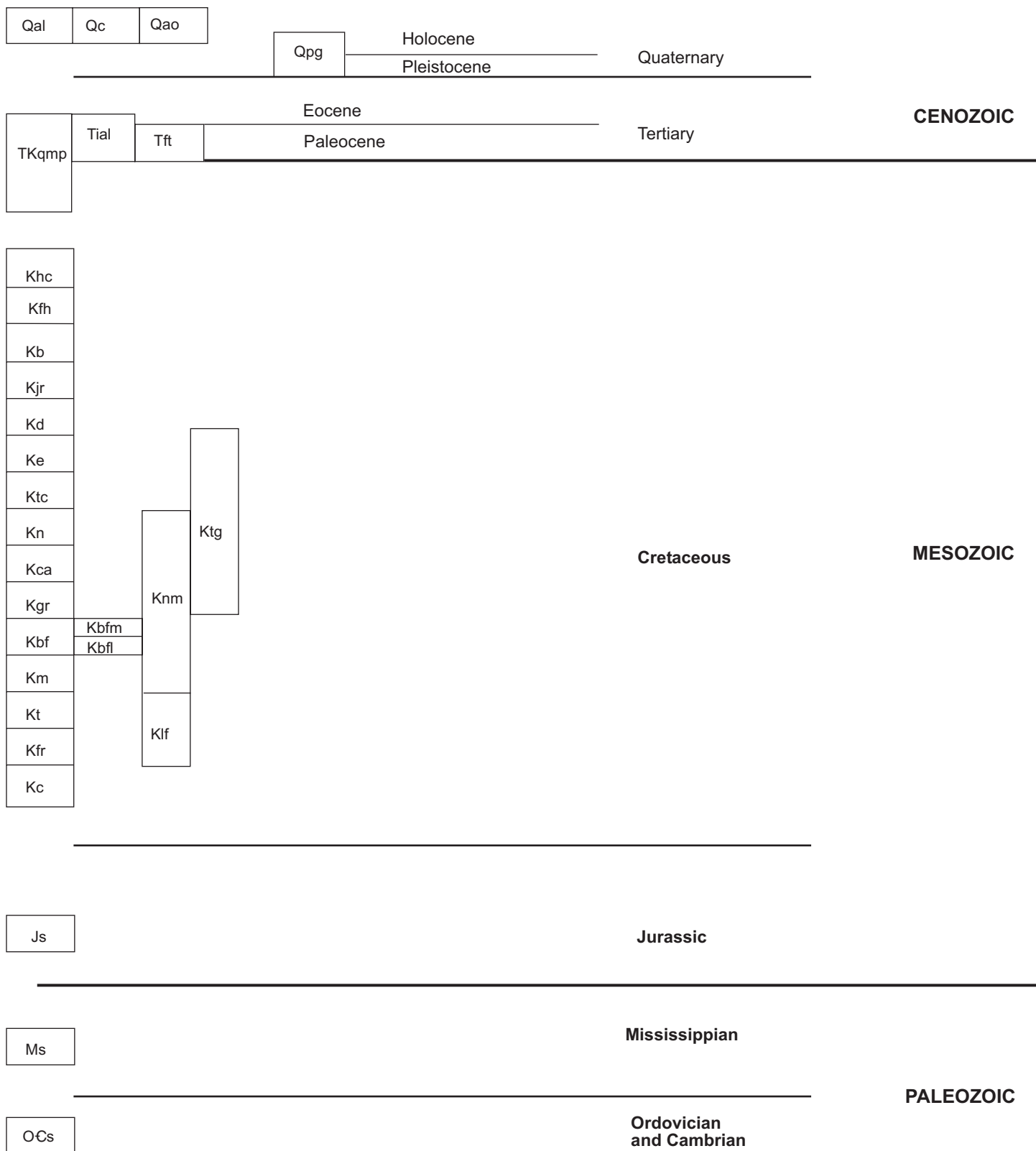


Figure 1. Age correlation chart of map units for Winnett 30' x 60' quadrangle.

DESCRIPTION OF MAP UNITS

- Qal FLOOD PLAIN AND CHANNEL ALLUVIUM (HOLOCENE) — Yellow-tan and gray-tan deposits of 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 at slightly higher elevations than modern flood plain alluvium. Thicknesses not measured.
- Qc COLLUVIUM (HOLOCENE) — Yellow-tan, tan, cream, and gray-tan weathering, nonstratified surface deposits of minor slumps and sheet-wash proximal to alluvium of a few modern drainages, and dried lake deposits; located in northwest map area. Thickness ranges from 1 to 20 ft.
- Qao OLDER QUATERNARY ALLUVIUM (HOLOCENE) — Light gray to yellowish white weathering deposits of unconsolidated clay, silt, sand, and some small gravel of predominantly limestone composition; moderately sorted. Mapped in northern half of quadrangle adjacent to modern streams, generally slightly above modern alluvial flood plains; includes unmapped terrace deposits; poorly exposed except where undercut by streams. Thin soils developed on unit. Thickness ranges from 10 to 60 ft.
- Qpg PEDIMENT GRAVEL AND GRAVEL ALLUVIUM OF DISSECTED BRAID PLAINS (QUATERNARY) — Light gray to yellowish-white and gray-brown weathering deposits of uncemented to locally cemented, cobbles in pebble, sand, and clay matrix. Cobbles predominantly light gray, rounded clasts of Madison Group limestone, commonly with powdery white, calcareous coatings; in western map area, composition includes green and brown alkalic igneous rocks derived from Judith Mountains. Cemented intervals 1 to 5 ft thick, with iron-rich calcareous matrix commonly weathering reddish to yellow-orange or rusty brown. Unit includes thin veneer of gravel on pediment surfaces and several levels of thicker gravels apparently deposited in broad alluvial fans now largely removed. Unit occurs in two broad areas extending from the Judith Mountains in westernmost map area, and in several isolated patches along high elevations on both sides of McDonald Creek in south part of map; unit equivalent to Qab unit mapped on Lewistown quadrangle (Porter and Wilde, 1993; revised 1999) and on Musselshell quadrangle (Porter and Wilde, 1999). Thickness not measured; from less than 1 ft to 10 ft.
- Tial ALKALIC INTRUSIVE ROCKS, UNDIVIDED (TERTIARY) — Medium brown, green-brown, to yellow-brown, brick red, and orange weathering; ultramafic, porphyritic, and commonly containing small and large (1/2 to 18 inches in diameter) angular, slightly metamorphosed blocks of sedimentary bedrock, generally shale. Intrusions commonly deeply weathered, poorly to moderately resistant, and form crumbly, coarse rubble; occur as low, slightly resistant dikes forming streaks across ground surface (secs. 5, 6, T14N, R25E; note this body has been called the Winnett sill, but its sill orientation is unclear to the present mappers), as dike ridges with relief of 60 ft or more (sec. 1, T15N, R25E), and as isolated low-relief

plugs (sec. 7, T15N, R25E); sills have been reported farther south in Elk Creek drainage of Musselshell 30' x 60' quadrangle (Johnson and Smith, 1964) but were not observed in this map area. Strike orientation of dikes is north 55° to 70° east. Intrusions within map area are not clearly associated with faulting but this relationship is observed by Johnson and Smith (1964) farther to south. Refer to: Johnson and Smith (1964), Kohrt (1991) for Black Butte area); Marvin and others (1980), Ross (1926), and Scambos (1991) for detailed discussion of composition and emplacement history of these igneous intrusions.

- Tft TULLOCK MEMBER, LOWER MEMBER OF FORT UNION FORMATION (LOWER TERTIARY) — Alternating layers of light to medium gray and tan sandstone, siltstone, and claystone; white-weathering surfaces commonly associated with claystones and siltstones; claystone surfaces occasionally weather to popcorn texture. Beds lens shaped and variable in width and length. Contact with underlying Hell Creek Formation marked by distinctive color change and placed above a thin (6 in. to 4 ft), black to dark brownish-gray, carbonaceous claystone containing thin coal seams and lenses. Unit occurs in small, isolated erosional remnants near center of ridge between Cottonwood Creek and Blood Creek and in one small area on ridge between Blood Creek and Dovetail Creek in west-central part of the map. Dips nearly flat to less than 1 degree. Only basal 40 to 60 ft of formation remain.
- TKqmp QUARTZ MONZONITE AND SYENITE PORPHYRY (PALEOCENE OR UPPER CRETACEOUS; TKqm of Goddard, 1988) — Phenocrysts of plagioclase (oligoclase and andesine), potassium feldspar, pyroxene, hornblende, and minor quartz in gray groundmass; includes some quartz diorite, monzonite, and rhyolite porphyry; also forms dikes and sills; large masses of syenite porphyry at Maginnis Mountain and Lewis Peak.
- Khc HELL CREEK FORMATION (UPPER CRETACEOUS) — Composed of nonmarine sandstones, siltstones, and claystones in three distinct intervals. *Lower interval* consists of very discontinuous, thinly interbedded, olive-gray to brownish-gray, sandy siltstones, and claystones with occasional thin beds of light-gray sandstone; some claystones bentonitic. Thickness varies from 30 to 60 ft. *Middle interval* consists of light-gray to yellowish-gray sandy siltstones and fine- to medium-grained sandstones; locally calcareous; contains conspicuous, cross-bedded, concretionary zones that weather light-brownish-gray to yellowish-brown and often form log-like masses. Contains many shallow channel features with common basal conglomeratic lag; locally, channels have cut through lower interval into top of Fox Hills Formation. Middle interval makes up more than half of entire formation in this area. Unit often tree-covered. Ranges from 125 to 150 ft thick. *Upper interval* consists of interbedded yellowish-gray, medium-grained sandstone and olive-gray to brownish-gray siltstone and claystone. Upper contact placed below a distinct color change at a very dark brownish-gray silty claystone. Thickness ranges from 40 to 90 ft. Bones, leaf and stem imprints, and plant fragments occur at many locations and throughout the formation. Accurate dips difficult to obtain, but generally less than 2 degrees throughout the area, except along Cottonwood Creek and near the Cat Creek Anticline. Formation forms main ridge areas between eastward-flowing streams in northern part of map area. Total formation thickness is 185 to 225 ft. Johnson and

Smith (1964, p. 55-56) report thickness of 214 ft just east of Winnett quadrangle.

- Kfh **FOX HILLS FORMATION (UPPER CRETACEOUS)** — Consists of two distinct intervals. *Lower interval* consists of interbedded sandstone, siltstone, and claystone beds that often contain small ironstone concretions and small, light brownish-gray sandstone nodules. Becomes more clay-rich at base; contact transitional with underlying Bearpaw Shale. Interval generally forms gentle, grass-covered slopes at base of steep hills near valley bottoms; ranges from 10 to 30 ft thick. *Upper interval*, most conspicuous part of the formation, light gray, fine- to very fine-grained sandstone weathering to tan or light brownish-gray. Generally unconsolidated to slightly consolidated; appears massive. Forms benches above interbedded lower interval and ledges and small hills where better cemented. Ledge-forming sandstone often calcareous, weathers rusty brown, and generally contains either ripple marks or thin cross beds; contains fossilized plant fragments in a few locations. Interval 40 to 90 ft thick. Upper contact placed at top of a brownish-black to purplish-black, very carbonaceous, silty claystone forming conspicuous ledge where visible, but often covered; bed contains streaks of coal and often plant fragments; distinct color change from generally light-colored Fox Hills to darker olive-brown tones of lower Hell Creek marks contact. Contact throughout most of area appears conformable. Formation forms basal part of steep hills bordering creek valleys. Total formation thickness ranges from 60 to 120 ft. Johnson and Smith (1964, p. 50-53) report thicknesses of 63 ft to 141 ft just east of Winnett quadrangle.
- Kb **BEARPAW SHALE (UPPER CRETACEOUS)** — Consists of medium- to dark-gray, fissile shale weathering to lighter gray or brownish-gray surface. Contains a few very thin (1-3 in.), laterally inconsistent, yellowish-gray bentonite beds, and a few scattered white to light gray weathering limestone concretions that commonly contain marine fossils. Becomes increasingly sandy upward, grading into interbedded siltstones and sandstones at base of overlying Fox Hills Formation. Outcrops form flat to very gently rolling topography exposed in bottoms of eastward-flowing creeks in northeastern part of map area. Less than 200 ft of this formation crops out in this area, but Cobban (1953, p.101) reported a thickness of 1318 ft east of Winnett quadrangle.
- Kjr **JUDITH RIVER FORMATION (UPPER CRETACEOUS)** — Composed of three distinct intervals. *Lower sandstone unit* (approx. 78 ft) weathers yellow-gray, very fine- or fine-grained, massive to poorly bedded, burrowed to bioturbated; more resistant, coarser-grained and containing brown, fist-size nodules in upper part, with uppermost approximately 7 ft composed of hard, light-brown, ferruginous, locally coarse-grained, concretionary, cross-stratified sandstone forming resistant ledge. *Middle unit* (approx. 140 ft) is green-gray weathering, fine-grained sandstones, siltstones, mudstones, and brownish carbonaceous shale; common plant imprints, coalified plant debris, and silicified wood; numerous conspicuous rusty-brown to purple-black weathering ironstone concretions. *Upper unit* (approx. 55 ft) composed of basal 10-ft yellow-gray to yellow-brown weathering fine-grained sandstone overlain by sequence of interbedded sandstone, mudstone, and carbonaceous shale with common small ferruginous concretions. Contact with underlying Claggett is transitional; contact with overlying Bearpaw Shale is relatively sharp above uppermost gray, sandy beds. Middle and upper units of formation commonly weather

to a badlands aspect. Total thickness of 273 ft measured by Cobban (1953, p. 98) east of Winnett quadrangle.

- Kcl CLAGGETT SHALE (UPPER CRETACEOUS) — Dark gray fresh surfaces commonly weathering to soft brown; fissile except on fresh exposures where it is more blocky weathering. Upper middle portion contains characteristic deep orange weathering, smooth, ovoid to discoid, calcareous concretions up to 3 ft in diameter occurring at irregularly spaced horizons; these concretions are characteristically highly fractured with common yellow calcite vein filling, and weather into mounds of small, sharp-edged, orange-brown fragments. Numerous bentonite layers from 1 to 5 inches thick occur in lower one-quarter of unit and commonly associated with thin layers of chert pebbles presumed reworked into lower Claggett beds from chert-pebble-bearing upper Eagle Formation. Commonly bare to sparsely vegetated. Thickness of 430 ft measured by Cobban (1953a, p. 98) east of Winnett quadrangle.
- Ke EAGLE FORMATION (UPPER CRETACEOUS) — Composed of 3 distinct intervals. *Lower interval* (Virgelle Member of some workers) is white- to yellow-tan weathering, friable to moderately hard, fine-grained, chert-bearing sandstone, commonly concretionary in long, oval forms, locally burrowed to bioturbated, mostly massive; commonly forms prominent low cliffs or scarps on outcrop; uppermost sandstones are cross-stratified and capped by pedestals of dark brown concretionary beds as seen in exposures north of Winnett. Middle interval is unresistant, poorly exposed, tan, light gray, and greenish mudstones and thin chert-pebbly sandstones with interbedded thin lignite seams. *Upper interval* is yellow-gray weathering, variably soft to moderately resistant, fine- and medium-grained, commonly cross-stratified, chert-bearing sandstone, frequently weathering in large, bulbous, calcareous concretionary forms; uppermost beds are thin and contain small hard rounded dark-red ironstone concretions and lenses of black chert pebbles. Thickness of 288 ft determined for composite section just beyond east edge of map area (Johnson and Smith, 1964, p. 41-44).
- Ktc TELEGRAPH CREEK FORMATION (UPPER CRETACEOUS) — Medium to light gray weathering, noncalcareous, sandy shale. Lower part contains characteristic thin beds of small, dark red ironstone concretions weathering to angular chips. Upper part becomes silty to sandy, with characteristic bands of calcareous, tan to chocolate-brown weathering, dark gray siltstone concretions. Upper contact is transitional and generally placed at base of lowest cliff-forming sandstone of overlying Eagle Formation; lower contact with Niobrara Formation shales is generally obscure beneath soils and is approximately located throughout map area except where lumped with other units on steeply dipping north limb of Cat Creek Anticline. Thickness of about 164 ft given by Johnson and Smith (1964, p. 38) for outcrops at Winnett in map area.
- Ktg TELEGRAPH CREEK FORMATION THROUGH GREENHORN FORMATION, UNDIVIDED (UPPER CRETACEOUS) — These units are mapped together along steeply dipping north limb of Cat Creek Anticline in center of map area.
- Kn NIOBRARA FORMATION (UPPER CRETACEOUS) — Dark to medium olive-gray, fissile shale containing numerous thin bentonite beds. Upper unit characteristically

calcareous and yellow-orange weathering in contrast with noncalcareous, gray weathering lower unit. Lower unit slightly sandy and contains sparse, white weathering, rounded, calcareous concretions from fist-size to about 1.0 ft in diameter, particularly in upper part. Thin (1- to 3-in.) bentonite layers, especially in lower part of lower unit, commonly weather orange, providing contrast with underlying nonbentonitic shales of upper Carlile Formation. Commonly associated with bentonitic layers of lower unit are small limestone nodules coated and invaded by crumbly, coarsely crystalline, reddish to white or clear calcite or aragonite that extends along bedding planes and becomes fibrous in form. Small (0.5 inch) irregular fragments of *Inoceramus* shell prisms occur sparsely throughout lower and upper units. Upper calcareous unit shows abundant tiny white coccolith tests on bedding planes, equivalent to the "first white specks zone" of U.S. and Canadian subsurface. In map area, outcrops of Niobrara are generally poor owing to low dips across area and development of overlying soils; good exposures limited to steep creek bank cuts. Contact with overlying Telegraph Creek Formation approximately placed, based on contrasting calcareous content and soil color of upper Niobrara and lower Telegraph Creek shales. Lower contact generally poorly exposed but approximately placed above last exposure of upper Carlile Formation shales that characteristically bear numerous white weathering football-size concretions, and/or below zone of thin orange weathering bentonite layers of lower Niobrara. A basal Niobrara bed recognized by Johnson and Smith (1964) in Musselshell River area to east, and called Sage Hen limestone bed by Lupton and Lee (1921, p. 264), not well developed in Winnett map area. Lower unit of formation about 206 ft thick; upper unit about 173 ft thick (Johnson and Smith, 1964, p. 34).

- Knm NIOBRARA FORMATION THROUGH MOWRY SHALE, UNDIVIDED (UPPER CRETACEOUS) — These units mapped together along steeply dipping narrow outcrop band around faulted intrusive core of Black Butte, easternmost exposed pluton of Judith Mountains at west edge of map area.
- Kca CARLILE SHALE (CRETACEOUS) — Dark gray to medium gray weathering, noncalcareous shale, generally poorly exposed throughout map area and recognized by characteristic sequence of concretion types. *Lower unit* contains characteristic horizons of oval, dark red ironstone concretions that weather to small, angular, "chippy" fragments forming rubbly patches in blue-gray fissile shale; a barren, blue-gray weathering shale occasionally exposed below this more resistant concretion-bearing shale (unit equivalent to Blue Hill Member of Carlile in Black Hills region; barren shale included in Kcc1 by Johnson and Smith (1964, p. 29)). *Middle unit* contains characteristic zone of large, sandy, dull orange weathering concretions, commonly highly fractured and containing cone-in-cone structures (unit equivalent to Turner Sandstone Member of Carlile in Black Hills region). *Upper unit* contains common to locally abundant white-gray weathering, rounded, football-size concretions (unit equivalent to Sage Breaks Member of Carlile in Black Hills region). Upper contact of Carlile approximately located below thin orange weathering bentonite layers of lower Niobrara; lower contact approximately located except where underlying calcareous shales of Greenhorn are well exposed. *Note:* Very rarely, a thin (approx. 10-12 ft) unit of yellow-orange weathering shale, concretionary limestone lenses, and orange-stained, thin, white bentonite beds exposed at base of Carlile; unit is equivalent to Fairport Member of Carlile of Black Hills region, and unit

Kcc1 of Johnson and Smith (1964). Thickness of 310 ft for Carlile measured by Cobban (1951, p. 2190) east of Winnett quadrangle.

Kgr GREENHORN FORMATION (UPPER CRETACEOUS) — Medium to light gray, calcareous shale, weathering characteristic pale yellow to creamy white. Fresh surfaces rarely exposed; unit generally recognized by soil color and texture in small patchy weathered exposures across grassy surfaces. Basal beds contain large (up to 1.5 ft diameter), yellow-gray to lavender-gray calcareous, septarian concretions with vein filling of yellow and dark red-brown calcite, overlain by a thick (1-3 ft) orange-stained white bentonite bed. Bedding surfaces contain tiny whitish coccolith tests; formation equivalent to “second white specks zone” of U.S. and Canadian subsurface. Thickness of 33 ft measured by Cobban (1953a, p. 99) east of Winnett quadrangle.

Kbf BELLE FOURCHE SHALE (UPPER CRETACEOUS)

Kbfm MOSBY SANDSTONE MEMBER — Brown weathering, light gray, very fine-grained to fine-grained, cross-stratified sandstone, commonly fossiliferous, locally calcareous; transitional above lower Belle Fourche shales. Composed of two sandstone ledges, each 5 to 6 ft thick, separated by 10 to 11 ft dark gray, clayey shale; upper sandstone overlain by about 6 ft fissile, dark gray, noncalcareous shale. Lower sandstone locally contains very fossiliferous lenses of gastropods and pelecypods. Thickness of approximately 29 ft measured by Johnson and Smith (1964, p. 26) within map area. *Note:* Johnson and Smith (1964) combined this unit with overlying Greenhorn Formation for mapping purposes.

Kbfl LOWER SHALE MEMBER, INFORMAL — Dark gray, noncalcareous shale, poorly exposed in map area. Lithologies observed across grassy slopes and small ravines, from base to top of interval: (1) characteristic dark purple-black to brown-black, metallic-looking, conchoidally fractured, dense, ironstone concretions up to 5 ft long but commonly less than 1 ft, with associated white to yellow-gray bentonites a few inches to 2 ft thick; occur in basal shale beds above Mowry contact and extend upward approximately 50 ft; (2) light blue-gray weathering sandy mudstone, highly jointed in several intersecting iron-stained planes forming brown-outlined polygons on outcrop face; recognized approximately 50 to 60 ft above member base; thickness uncertain; (3) dark gray, coarse- to medium-grained, cherty sandstone from several inches to 5 ft or more thick with chert pebbles common in upper few inches, underlain by 3 or more ft sandy mudstone; occurs approximately 120 ft above base of member; commonly forms low resistant ledge within generally unexposed shales of member; often recognized only by loose, rounded, weathered fragments and small blocks of cherty sandstone on ground surface; (4) prominent orange-weathering, commonly fractured, large, calcareous, sandy concretions characteristic of upper part of member, occasionally overlain by zone or bed of large, white weathering limestone concretions in turn overlain by shale that is increasingly sandy and transitional into

overlying Mosby Member within about 20 ft. Thickness of 303 ft given for member in map area by Johnson and Smith (1964, p. 24).

- Km MOWRY SHALE (UPPER CRETACEOUS) — Very light silvery-blue to light yellow-gray weathering. Composed of brown-gray, hard, brittle, thin-bedded, sandy siltstone and clayey shale in upper part, and light brown-gray, thin- to thick-bedded, fine- to medium-grained sandstone in lower part. Fish scales and small bone fragments throughout though not in all intervals. Thin white to orange-stained bentonite beds common throughout. Locally, thicker sandstones may be cross-stratified and glauconitic, and occasionally coarse-grained with chert granules or small pebbles in coarse fraction; occasionally chert-pebbly. Sandstones form resistant low ledges, cliffs, ridges and broad dip slopes throughout map area. Upper Mowry commonly observed as very light silvery-blue barren patches across slopes. Lowermost Mowry, where exposed, generally soft-weathering, dark brown, bentonitic, laminated claystone. Persistent 2- to 3-ft whitish bentonite bed near base probably is Arrow Creek bed of Reeside and Cobban (1960). Thickness of 197 ft given by Johnson and Smith (1964, p. 20) for locality south of Winnett quadrangle.
- Kt THERMOPOLIS SHALE (LOWER CRETACEOUS) — Dark gray to black shale, tan-gray sandy shale, olive-tan laminated very fine-grained sandstone, and medium-grained bedded sandstone; numerous thin bentonite beds throughout; generally poorly exposed throughout map area. Three members recognized but not mapped separately. *Lower, Skull Creek Shale Member*, approximately 175 ft, composed of glistening black, very fissile shale with numerous thin, iron-stained sandstone beds and laminae in lower part ("Dakota silt" interval of subsurface); common dark purple-red to purple-black ironstone concretions with metallic luster. *Middle, unnamed sandy member, informal*, approximately 312 ft, composed of thin beds and laminae of olive-gray, very fine-grained, ripple-laminated sandstones and interbedded dark gray clayey shale; numerous dark reddish-purple ironstone concretions; lower part of member contains a 1- to 6-inch thick chert-pebble bed. *Upper, Shell Creek Shale Member*, approximately 103 ft, dominantly medium gray-weathering, soft, fissile black shale; unit included in informal sandy member by Johnson and Smith (1964). Total thickness of 587 ft given by Porter *et al.* (1997, pl. 5) for locality south of Winnett quadrangle.
- Ktf THERMOPOLIS FORMATION AND FALL RIVER FORMATION, UNDIVIDED (LOWER CRETACEOUS) — These units are mapped together along steeply dipping narrow outcrop band around faulted intrusive core of Black Butte, easternmost pluton of Judith Mountains at west edge of map area (Goddard, 1988).
- Kfr FALL RIVER SANDSTONE (LOWER CRETACEOUS) — Tan-brown weathering, light gray-tan or buff-tan, commonly brown-speckled on fresh surfaces, fine-grained, quartzose. Cross-stratified and rippled 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 may be a sandstone or a medium gray sandy shale resting on Kootenai red beds. Thickness approximately 70 ft in map area (Johnson and Smith, 1964, p.13).
- Kk KOOTENAI FORMATION (LOWER CRETACEOUS) — Exposed in southwest corner of

map area on north-dipping flank of Big Snowy mountains anticlinorium. Dark to medium red, gray-green and minor buff-colored silty, blocky weathering shale, and fine- to coarse-grained, chert-bearing, feldspathic, cross-stratified sandstone. Thick basal sandstone (up to 100 ft; Third Cat Creek Sandstone of subsurface) is gray, medium- and coarse-grained, conglomeratic, chert-bearing, cross-stratified. Sandstones higher in section, interbedded with varicolored mudstones, are dominantly yellow and brown, thin-bedded, fine-grained, quartzose with minor chert and feldspar. Thin gray-white nodular limestone beds occur locally in section above basal sandstone. Thickness of 400-550 ft reported by Gardner (1950).

- Js JURASSIC SEDIMENTARY ROCKS, UNDIVIDED — Rocks poorly exposed in narrow faulted wedge on southwest side of Black Butte in northwest map area (Goddard, 1988). No thicknesses measured.

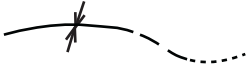
- Ms MISSISSIPPIAN SEDIMENTARY ROCKS, UNDIVIDED — Rocks poorly exposed between two ring faults on southeast flank of Black Butte in northwest map area. Predominant exposures are medium gray weathering Madison Group limestones (Goddard, 1988). No thicknesses measured.

- OCs ORDOVICIAN AND CAMBRIAN SEDIMENTARY ROCKS, UNDIVIDED — Rocks exposed on southeast flank of Black Butte in northwest map area (Goddard, 1988). No thicknesses measured.

GEOLOGIC MAP SYMBOLS



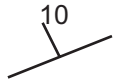
Contact; dashed where approximately located, dotted where concealed.



Synclinal fold showing trace of axial plane; dashed where approximately located, dotted where concealed. Arrow indicates direction of plunge where known.



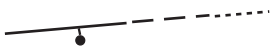
Anticlinal fold showing trace of axial plane; dashed where approximately located, dotted where concealed. Arrow indicates direction of plunge where known.



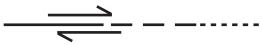
Strike and dip of bedding; degrees of dip indicated.



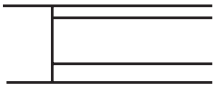
Strike and dip of vertical bedding.



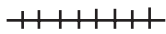
Fault; dashed where approximately located, dotted where concealed. Ball and bar on downthrown side.



Strike slip fault; dashed where approximately located, dotted where concealed. Arrows indicate relative horizontal movement of rocks on either side of fault plane.



Indicates a change in map units shown, based on combining units in (1) areas of steep dip, and/or (2) inadequate outcrop for assuming approximate contact locations.



Igneous dike or plug

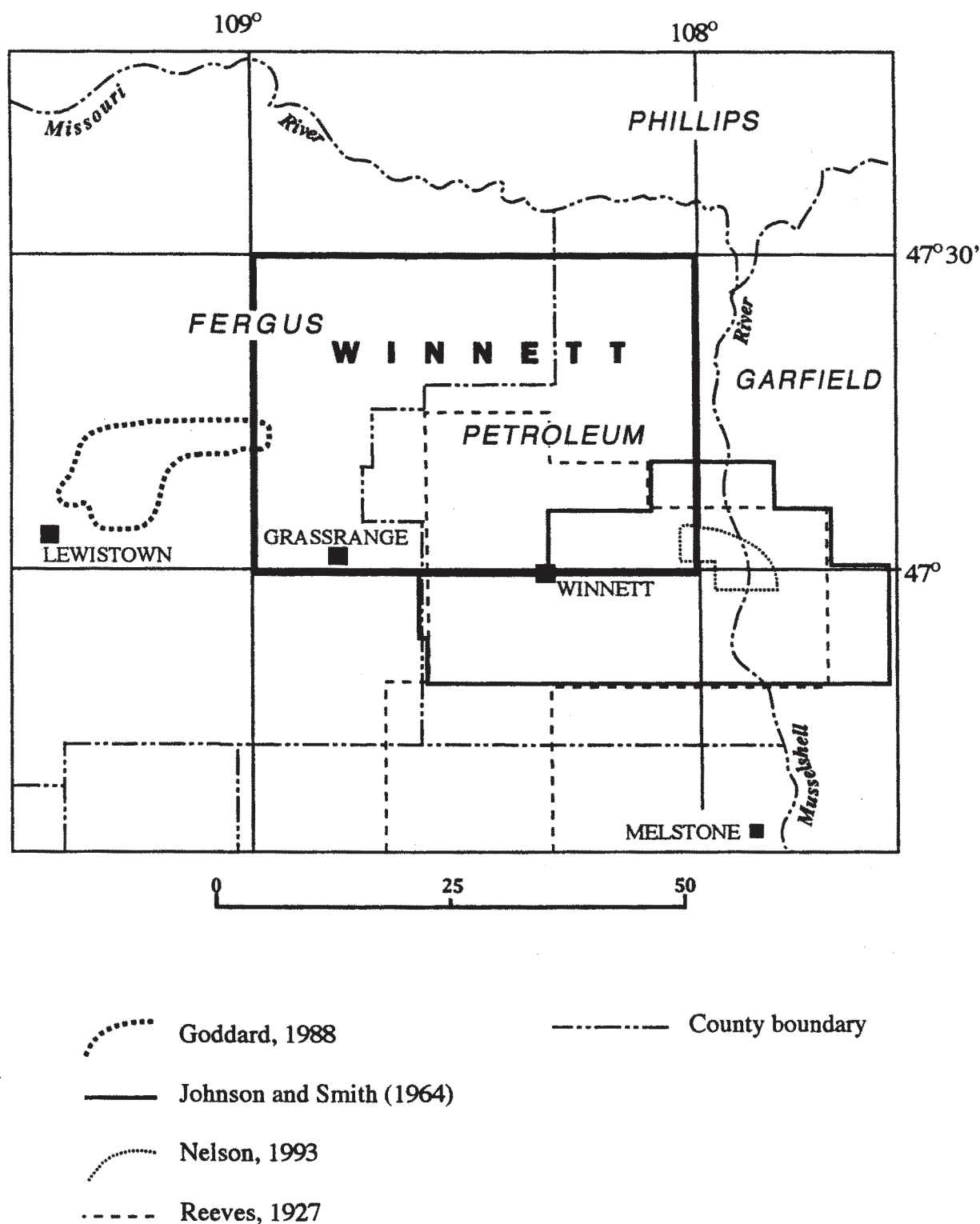


Figure 2. Index map of sources of previous geologic mapping in and adjacent to Winnett quadrangle. See references for complete citation.

SOURCES OF PREVIOUS GEOLOGIC MAPPING

- Goddard, E. N., 1988, Geologic map of the Judith Mountains, Fergus County, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1729, scale 1:31,680.
- Johnson, W. D., and Smith, H. R., 1964, Geology of the Winnett-Mosby area, Petroleum, Garfield, Rosebud, and Fergus Counties, Montana: U. S. Geological Survey Bulletin 1149 , 91 p., map scale 1:63,360.
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ADDITIONAL SOURCES OF GEOLOGIC INFORMATION

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