GEOLOGIC MAP OF THE HARLOWTON 30' x 60' QUADRANGLE

CENTRAL MONTANA

by

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GEOLOGIC SUMMARY

The Harlowton quadrangle is located in central Montana in parts of Sweet Grass, Stillwater, Golden Valley, and Wheatland Counties (fig.1). The northeast-trending Shawmut Anticline and the northwest-trending Womans Pocket Anticline dominate the northern part of the quadrangle. Two large domes, Big Coulee and Hailstone, lie in the southeast part of the quadrangle. Along the southern quadrangle boundary a series of northeast-trending normal faults forms the western end of the northwest-trending Lake Basin Fault Zone

Gravel-covered benches obscure bedrock in some areas, but elsewhere, incision by the Musselshell River drainage has provided excellent exposures of the stratigraphic section. The youngest bedrock exposed in the quadrangle is the lower part of the Tongue River Member of the Tertiary Fort Union Formation. The oldest rocks exposed are in the Lower Cretaceous Kootenai Formation.

Sources of Previous Geologic Mapping in the Quadrangle

This report integrates previous geologic mapping for the quadrangle contained in USGS Bulletins and Water-Supply Papers published from 1918 through 1956 (fig. 1). It provides extensive new mapping of both the Tertiary and Upper Cretaceous stratigraphic sections. Map units have been integrated with recent 1:100,000-scale geologic mapping completed by MBMG in the south-adjacent Big Timber quadrangle (Lopez, 2000), north-adjacent Big Snowy Mountains quadrangle (Porter and Wilde, 1996), and east-adjacent Roundup quadrangle (Wilde and Porter, 2000) (fig. 1)

Stratigraphic Notes for the Harlowton Quadrangle

Occurrence of coal

This 1:100,000–scale quadrangle contains parts of three coal fields: the western part of the Bull Mountain Coal Field, the northeastern part of the Livingston Coal Field, the southern part of the Lewistown Coal Field. Currently, the coal in this area is considered sub-economic for commercial-scale mining; its rank ranges from lignite to bituminous. There are from 17 to 21 separate beds that are most often found within interbedded sequences of fine- to medium-grained sandstone, siltstone, and claystone. The coal most likely formed in overbank and interfluvial-swamp environments within persistent basins formed during uplift of the Rocky Mountains. Most of these coals are lenticular in shape and show a wide variation in thickness and rank. The coal-bearing sedimentary sequences are mainly in the Tongue River Member of the Tertiary Fort Union Formation. To a much lesser extent, the underlying Lebo and Tullock Members of the Fort Union Formation, and the successively underlying Upper Cretaceous Hell Creek, Judith River, and Eagle Formations also contain coal. In general, the coals appear to thin toward the west. Today, the outcrops of these thin coals are often covered by slope-wash material and do not present obvious marker horizons. Two beds have been mined for local use, but commercial mining is not economical due to the thin and lens-like nature of the coal beds and the steep dip present in many areas.

Stratigraphy and nomenclature

Many of the Upper Cretaceous and Tertiary stratigraphic units exposed in this map area contain a much higher percent of sand than is seen farther to the east. In addition, the Tertiary and the youngest Cretaceous units have a content of volcanic grains and fragments that change the overall appearance of the outcrops. Both the sand content and the volcanic content increase noticeably westward across the map area.

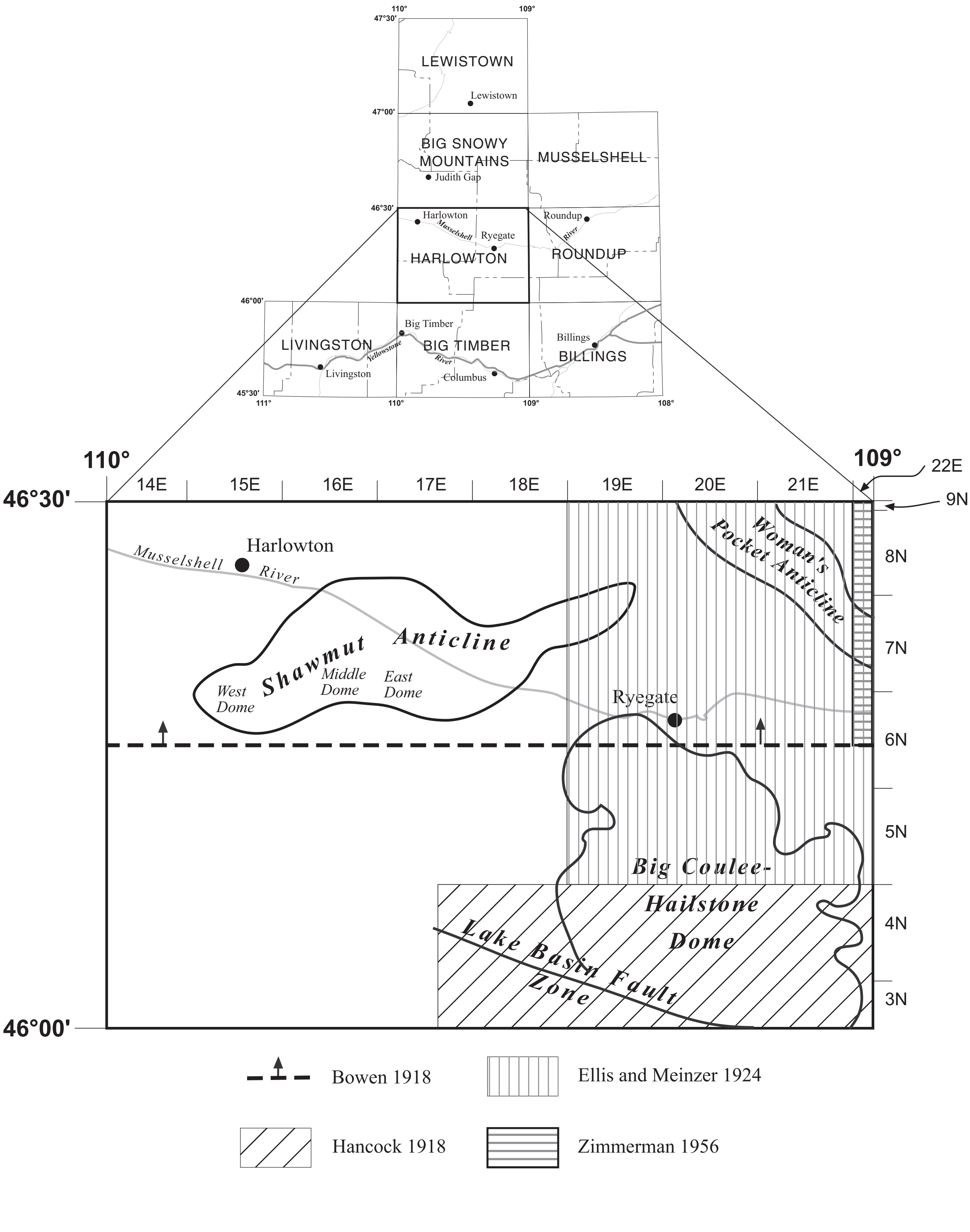


Figure 1. Location map for Harlowton quadrangle showing areas covered by older geologic maps within the quadrangle (see Sources of Previous Geologic Mapping), and location of adjacent geologic maps recently published by MBMG.

Fort Union Formation. A question has arisen concerning whether or not all three members of the Fort Union Formation are present in this area. The westward increase in sand and volcanic grain content has made discernment of the members difficult, particularly in the western part of the quadrangle. Previous unpublished maps covering various parts of this 1:100,000 quadrangle have divided the Fort Union into only two members, the Tongue River and the Lebo. The basal Fort Union (the Tullock Member), was then included either as the upper part of the Hell Creek Formation, or the lower part of the Lebo Member of the Fort Union Formation, depending on the placement of the contact.

The current investigators, however, have been able to map all three members throughout the outcrop area of the Fort Union Formation for this map sheet. Therefore, all three members are shown on this map. Reinterpretation of this sequence has resulted in the recognition of several structures and faults that were not previously mapped.

Lance Formation. Use of the term Lance has been extended into this area from the east (Roundup quadrangle, Wilde and Porter, 2000). As used here, the Lance Formation is the stratigraphic equivalent of the combined Hell Creek and Fox Hills Formations. The Fox Hills Formation can be recognized throughout the area of outcrop for this part of the stratigraphic sequence. However, for this 1:100,0000 scale quadrangle, the Fox Hills Formation is often too thin and/or the beds dip too steeply to allow separation of the two formations at the 1:100,000 scale.

Lennep Formation. In this area, the term Lennep has previously been applied to a sequence of beds stratigraphically positioned between the Upper Cretaceous Bearpaw Shale and the Upper Cretaceous strata that overlie them. The Lennep included all of the Fox Hills Formation and the lower part of the Hell Creek Formation, as these formations are currently mapped to the east and south. In order to maintain nomenclature and stratigraphic interpretations consistent with mapping in adjacent quadrangles, the term Lennep is not used in this interpretation**.** Therefore, the boundary between the Fox Hills and Hell Creek Formations was mapped for this report. The contact was placed between the beach sands of the Fox Hills Formation and the fluvial or inter-fluvial sediments of the lower Hell Creek Formation, as it is mapped elsewhere in the state.

Claggett Formation. In unpublished mapping covering parts of this quadrangle, existence of the Claggett Formation has been questioned. In the western part of this quadrangle, the Claggett consists of interbedded shale beds and lens-shaped sandstone beds that form a transitional zone between the overlying Judith River Formation and the underlying Eagle Formation. Two sandstone beds located near the middle of the formation often form small resistant ridges locally, where the formation is exposed.

Marias River, Mowry, and Belle Fourche Formations. On early geologic maps of all or parts of central Montana (Bowen, 1918; Hancock, 1918; Ross, 1955), the Lower and lower Upper Cretaceous interval from the top of the Kootenai Formation to the base of the Telegraph Creek Formation was mapped as a single unit, the Colorado Shale. On recently published 1:100,000-scale quadrangle maps (Big Snowy Mountains, Porter and others, 1996; Musselshell, Porter and Wilde, 1999; Big Timber, Lopez and others, 2000) (fig. 1), this interval has been subdivided into its component formations, based on stratigraphic position and lithologic affinity with formations mapped in the Black Hills region to the southeast.

However, on the recently mapped Lewistown 1:100,000-quadrangle (Porter and Wilde, 1993, revised 1999) (fig. 1), recognition is given to the transition of the upper part of this Colorado Shale into facies more typical of the stratigraphically equivalent Marias River Formation described for west-central Montana by Cobban and others (1976). The Marias River contains the Floweree, Cone, Ferdig, and Kevin Members, in ascending order, whose approximate eastern equivalents are, respectively, the Belle Fourche, Greenhorn, Carlile, and Niobrara Formations of east-central Montana. In the Harlowton 1:100,000-scale quadrangle area, the change to more western-appearing facies is again observed, now also involving units below the Marias River Formation -- the Belle Fourche and Mowry Formations. In these latter two formations a substantial increase in sandstone content characterizes the change. The eastern formation names are retained, however, although aspects of the western Blackleaf Formation, underlying the Marias River Formation, are noted. In the upper Marias River, the Kevin Member additionally has acquired characteristics that relate it to the upper Cody Formation mapped to the southwest in the Livingston 1:100,000 quadrangle (Roberts, 1954, 1972; Berg and others, 2000). It seems advisable, however, to restrict use of the term Cody to areas where the name Frontier is also used (W. A. Cobban, personal communication).

Three distinct regions of the marine sedimentary basin – eastern, western, and southwestern -- apparently influenced Late Cretaceous deposition in the Harlowton area. The resulting stratigraphic sequence records minor to major affinities with time-equivalent stratigraphic sequences of the eastern, western, and southwestern parts of the basin. The formations composing this interval in the Harlowton area are completely exposed on West and Middle (Devils Pocket) Domes of the Shawmut Anticline and partially exposed on East Dome and on Womans Pocket Anticline (fig. 1). The following stratigraphic resolution of the upper Colorado Shale is adopted for the Harlowton quadrangle:

(1) The Belle Fourche Shale name is retained above the Mowry Formation, although the formation is dominated by the Big Elk Sandstone. The Big Elk is treated as a member of the Belle Fourche. Its contact with sandstones of the underlying Mowry Formation, however, is somewhat arbitrary, based on topographic expression of stacked sandstones. There is no essential difference between sandstones assigned to the Mowry and those assigned to the Big Elk. Well logs adjacent to the south flank of West Dome indicate a fairly consistent break above a 30-ft sandstone assigned to the upper Mowry which can be identified on outcrop. Further study may indicate an erosional contact between these two units. The inclusion of the Big Elk within the Belle Fourche Formation is the same stratigraphic limit given to the Frontier Formation in the Livingston quadrangle by Lopez (2000), following Roberts (1966), although the Belle Fourche name is dropped. In the Harlowton area, typical upper Belle Fourche shale occupies the upper fifty feet of the formation.

(2) The Greenhorn Formation of eastern terminology is combined with the overlying lowermost beds of the eastern Carlile Formation. The two are mapped together as the Cone Member of the Marias River Formation of western terminology.

(3) The rest of the eastern Carlile interval, now showing marked change from typical lithologies of this unit, is also placed in the Marias River Formation, as an eastern extent of the Ferdig Member. However, the ironstone concretion-bearing shale typical of the lower Ferdig, and also typical of the lower Carlile, is not present in the Shawmut area, and may have been removed by erosion. An unconformity at the base of the Ferdig in the Shawmut area is further suggested by a locally occurring pebble-bearing quartzose sandstone resting directly on the Cone Member.

(4) In the Harlowton area, the Niobrara interval of eastern and east-central Montana has lost the calcareous content of its upper part and acquired a middle unit of glauconitic sandstone. The lower and middle parts of the interval bear significant affinity to the Kevin Member of the Marias River Formation to which they are assigned. The middle sandy part also bears affinity to the Eldridge Creek Member of the Cody Shale originating to the southwest in the Livingston area (Roberts, 1965). In the Livingston area, the Greenhorn/Cone, Carlile/Ferdig, and Niobrara/Kevin intervals are all incorporated into the Cody Shale overlying the Frontier Formation (Roberts, 1965; Berg and others, 2000). The Frontier Formation in the Livingston area is stratigraphically equivalent to all of the Belle Fourche Shale of east-central Montana, including the Big Elk Sandstone of the Harlowton area (Roberts, 1966, p.18-A19).

Acknowledgement

During several recent field seasons, the authors have had the benefit of discussions in the field with Drs. W. A. Cobban and T. S. Dyman of the U. S. Geological Survey in Denver, and with Dr. B. Carter Hearn, Jr. of the U.S. Geological Survey in Reston. These discussions have provided substantial assistance in evaluation of, particularly, the marine Upper Cretaceous stratigraphic section, and have greatly improved the content of this report.

Correlation of Map Units

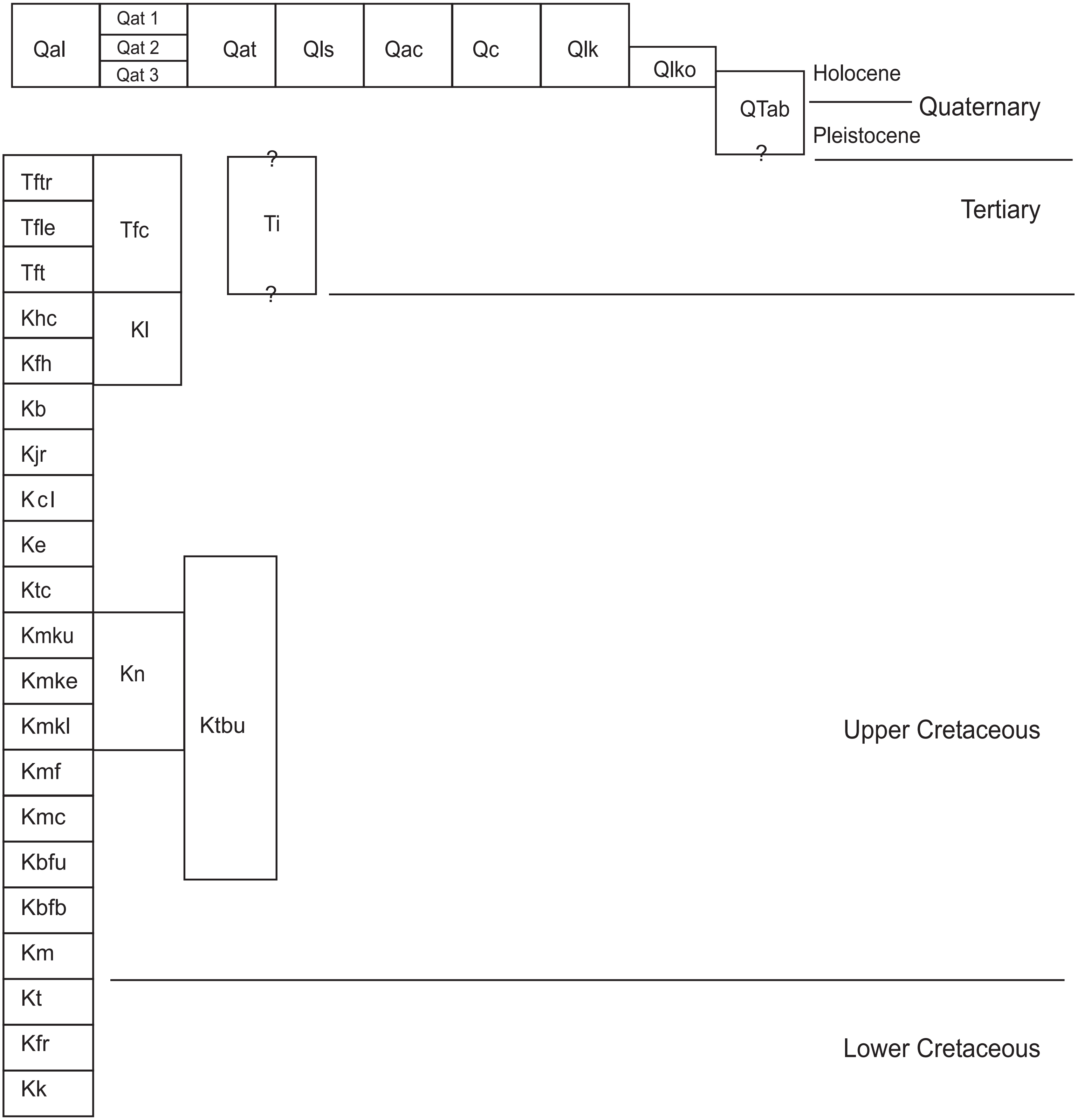


Figure 2. Correlation chart of map units for Harlowton 30' x 60' quadrangle.

DESCRIPTION OF MAP UNITS

Quaternary Deposits

Qal ALLUVIUM OF MODERN FLOOD PLAINS AND CHANNELS (HOLOCENE). Fine- to medium-grained, tan sand and silt, generally unconsolidated and located along the banks of modern streams. Some older fine gravel and fine to coarse sand of previous channels may also be included. Thickness ranges from a few inches to as much as 30 ft.

Qat ALLUVIAL TERRACE DEPOSITS (HOLOCENE). Gravel, sand and silt deposited by fluvial processes while the Musselshell River was at a higher level than present. Consists of intrusive, metamorphic and sandstone clasts from less than an inch to several inches in diameter. Found in isolated bodies from a few ft to several tens of ft above the current river level.

Qat1 ALLUVIUM OF YOUNGEST ALLUVIAL TERRACE, deposited at low elevation along modern streams.

Qat2 ALLUVIUM OF SECOND YOUNGEST ALLUVIAL TERRACE, deposited at slightly older and higher elevation of modern streams.

Qat3 ALLUVIUM OF THIRD YOUNGEST ALLUVIAL TERRACE, deposited at oldest and highest preserved elevation of modern streams.

Qls LANDSLIDE DEPOSITS (HOLOCENE). Deposits of mixed sediments originating from relatively sudden down-slope movement of a bedrock or surficial sediment mass.

Qac ALLUVIUM AND COLLUVIUM (HOLOCENE). Deposits of mixed sediments of both alluvial and colluvial origin, undivided.

Qc COLLUVIUM (HOLOCENE). Mixed sediments deposited on slopes as slope wash and in abandoned stream channels.

Qlk LAKE DEPOSITS (HOLOCENE). Fine-grained sands, silts and clays deposited from shallow standing water bodies; locally includes other surficial deposits of undetermined origin. Generally light-gray to tan in appearance. Thickness varies from a few inches to a few ft.

Qlko OLDER LAKE DEPOSITS (HOLOCENE). Light-yellowish tan and gray silty clay and clayey, sandy silt deposited in former bodies of standing water now dried. Locally includes other surficial deposits of undetermined origin. Thickness probably varies from a few inches to a foot or more, but was not measured.

Quaternary and Tertiary

QTab PEDIMENT GRAVEL (QUATERNARY OR TERTIARY). Surface deposits of medium to coarse sand, fine to medium gravel, and silt. Located on broad benches as large areas or as small erosional remnants. Derived from erosion of older formations and deposited by alluvial braid-plain processes including sheet wash across older flood plains. Deposits commonly are moved down slope to form modern colluvial surfaces. Thickness varies from a few inches to 2 ft.

Tertiary Rocks

Fort Union Formation. Not a mapped unit.

Overall, this formation consists of buff to yellowish gray sandstone, sandy claystone, claystone, shale, and coal beds. The entire formation contains a higher percentage of sand and a higher average grain size than is observed in areas to the east. Three members of the Tertiary Fort Union Formation are exposed in the Harlowton quadrangle:

Tftr TONGUE RIVER MEMBER OF FORT UNION FORMATION. Yellowish gray to gray, fine- to medium-grained, trough cross-bedded, planar-bedded or massive-appearing sandstone interbedded with lesser amounts of brownish gray carbonaceous shale, yellowish gray siltstone, and coal beds. Contains well-developed channels and stacked channel sequences that range from 20 to 100 ft in thickness. The sandstone channel sequences grade laterally into interbedded light-tan or gray siltstone and sandstone, dark-brown to gray siltstone and claystone, black to dark -brown carbonaceous claystone, and coal. The rocks are poorly consolidated to unconsolidated. Generally supports good growths of pines and other trees, and bushes. Only the basal 200 to 300 ft of the member are exposed in the area. In a few places, a coal bed that is 2- to 5-ft thick marks the base of the member, but it is more common for sandstone channel bases or interbedded sequences to form an indistinct conformable boundary with the underlying Lebo Member.

Tfle LEBO MEMBER OF FORT UNION FORMATION. Medium- to dark-gray and olive-gray shale that is commonly smectitic or carbonaceous, interbedded with silty shale, yellowish gray sandstone and siltstone, and thin lenticular shaly coal beds. Contains small-scale (5- to 40-ft thick), light-gray, fine- to medium-grained channel sandstones. It also contains areas of interbedded sandstone, siltstone, and carbonaceous claystone that weather dark-gray or greenish gray. Lateral changes from one lithologic sequence to another occur over short distances. The member often forms indistinct outcrops at the base of the Tongue River Member or in the bottoms of river valleys. Thickness of the member is difficult to determine (estimated between 180 to 300 ft, averaging about 250 ft) because it weathers to form gently rolling topography that appears flat, and is generally devoid of trees, but may be grass-covered or cultivated. Where steep dips occur, outcrops of sandstone will support tree growth similar to that of the Tongue River. The contact between the Lebo and the Tullock Member is generally an indistinct transitional zone and is generally covered. Where visible it is occasionally marked by a poor-quality coal bed or dark-gray to black carbonaceous claystone bed.

Tft TULLOCK MEMBER OF FORT UNION FORMATION. Yellowish gray, fine- to medium-grained, trough cross-bedded, planar-bedded or massive-appearing sandstone. Interbedded with lesser amounts of brownish gray and greenish gray claystone or dark-gray carbonaceous shale. It contains channel sequences that are similar in appearance to those of the Tongue River Member. Channel sequences are of a large scale than Lebo Member channels (10 to 60 ft thick), but of a smaller scale than the Lance Formation channels. Interbedded sequences are thinner, more tabular and more persistent than those in the underlying Lance Formation. This member weathers to a tan to light-brown surface and often supports growth of bushes and small pines. Thickness of the member varies from 170 to 250 ft, averaging about 210 ft. The contact with the Lance is transitional, and is often difficult to determine because of the sandy nature of both the Tullock Member and the Lance, although, there is often a change in the average grain size and an indistinct color change.

Ti IGNEOUS DIKES AND SILLS. Medium-brown weathering, dense to crumbly, coarse-grained, strongly micaceous bodies intruded into older sedimentary units as narrow, upright, elongate forms (dikes) or as generally flat lying, subparallel units (sills). On West Dome of Shawmut Anticline, two apparently separate bodies occur subparallel to bedding within the Fall River Formation. Based on the dominant mineral composition of plagioclase feldspar, amphibole, and biotite of these bodies, B. C. Hearn, Jr. of the U.S. Geological Survey (personal communication, 1999) associates these two sills with the Crazy Mountains igneous series rather than with the more exotic olivine-rich igneous series of the central Montana Plains. A vertical dike (probably two closely spaced dikes) of unknown petrography is reported by Model (1972) in SE/4 NE/4 NE/4 section 28, T. 6 N., R.16 E., and earlier reported by Garrett and others (1951, p. 44). A number of northeast-trending dikes are mapped in the southwest part of the quadrangle. These commonly show a significant baked zone developed in the adjacent sedimentary rock.

Upper Cretaceous Rocks

Kl LANCE FORMATION. Contains the combined lithologies of the Fox Hills littoral coastline environment sandstones and the overlying fluvial and interfluvial deposits of the Hell Creek Formation. The Lance Formation in the Harlowton quadrangle contains a high percent of sand, and the Fox Hills Formation (locally, as thin as 10 ft but always present) may be partially removed by Hell Creek channels eroding into the underlying lithology.

Khc HELL CREEK FORMATION. This formation contains at least two lithologic units. The first consists of large, well-formed, trough cross-bedded channel sandstones that are from 10 to more than 80 ft thick. They weather to a light-brown to tan surface similar to those found in the Tullock Member of the Fort Union Formation. These sequences are often cliff- or ledge-forming, fine- to coarse-grained, thick-bedded to massive-appearing sandstone. Overall, they are of larger scale than channels in the Tullock Member of the Fort Union Formation. This sandy lithology grades laterally into the second lithology; interbedded claystones, fissile shales, siltstones, and sandstones that weather to a dark-brown, bluish to greenish gray or tan surface. The contact between the fluvial and overbank deposits of the basal Hell Creek and the shoreline deposits of the overlying Fox Hills is locally erosional where Hell Creek channels have cut into the underlying shoreline deposits. The contact is placed at the base of a poor-quality coal bed that changes laterally into a carbonaceous claystone or siltstone when channels are not present. In several outcrop areas, the basal Hell Creek contains a coal-rich shale and has weathered to a distinctive white surface that is very similar in appearance to the Colgate Member of the Fox Hills Formation in the Cedar Creek anticlinal structure of eastern Montana. Total thickness is from 350 to 450 ft. Supports sparse pine growth locally.

Kfh FOX HILLS FORMATION. The littoral shoreline deposits of the Fox Hills Formation consist of thin layers of interbedded sandstone, siltstone, and claystone overlain by well sorted, very fine- to medium-grained, upward-coarsening, cross-bedded, poorly consolidated sandstone. Generally appears as the more gentle grass-covered slopes at the base of steep hills and cliffs formed by the Lance Formation. Becomes more sandy upward forming an upward-coarsening sequence beneath the fluvial and overbank deposits of the overlying Hell Creek. The contact with the underlying shale may be either transitional or erosional depending upon the position of channel sequences. Total thickness ranges from 10 to 110 ft.

Kb BEARPAW SHALE. Medium- to dark-gray, fissile, marine shale that weathers to a brownish gray surface. Outcrops form flat to very gently rolling topography that is locally grass-covered. Contains a few scattered light-gray limestone concretions that are generally fragmented, and locally contain marine fossils. Becomes increasingly sandy upward and grades into the interbedded siltstone and sandstone at the base of the Fox Hills Formation. Thickness varies from less than 300 to more than 800 ft.

Kjr JUDITH RIVER FORMATION. Exposed on flanks of Shawmut and Womans Pocket Anticlines. Consists primarily of medium- to fine-grained, light-brown to tan sandstone. Generally does not form prominent ridges or cliffs. Outcrops appear as sandy, grass-covered hills that sometimes have an orange tint when compared to surrounding formations. Central part of this formation sometimes contains dark-brown interbedded siltstone, claystone and coal; but where folded, this part of the formation is thinned or missing. The Judith River Formation ranges from 300 to 500 ft thick.

Kcl CLAGGETT SHALE. Primarily brown, fissile shale that contains numerous lenticular fine-grained sandstone beds. A persistent sandstone interval in the middle of the formation forms a distinct bench in areas of low dip, and a distinct ridge where dips are steeper. The formation locally contains orange-weathering, oval, commonly fragmented, calcareous, septarian concretions. Formation varies from 180 to 300 ft thick.

Ke EAGLE FORMATION. Light-gray to tan, fine- to medium-grained sandstone that often forms low cliffs and ridges. It may also form low, undissected topography. Forms the rim of Woman's Pocket Anticline and rims the eroded basins of Big Coulee and Hailstone Domes. Thickness ranges from 400 to 360 ft in well logs in T. 6 N., R. 16 E. and T. 5 N., R. 18 E., respectively.

Ktc TELEGRAPH CREEK FORMATION. Medium-gray to light-yellowish gray-weathering sandy siltstone, blocky shale, and fine-grained sandstone. Poorly exposed on Shawmut Anticline and Womans Pocket Anticline; better exposures occur on Big Coulee and Hailstone Domes. A pronounced yellowish gray-weathering sandstone in the middle of the formation forms a prominent bench where exposures are good, or a subtle slope break where the section is covered. Well log in sec. 30, T. 6 N., T. 16 E. records a thickness of 220 ft and a high sandstone content; elsewhere in well logs along south flank of Shawmut Anticline, thickness are in range of 75 to 160 ft.

Ketc EAGLE AND TELEGRAPH CREEK FORMATIONS, UNDIVIDED.

Ktbu TELEGRAPH CREEK FORMATION THROUGH UPPER MEMBER, INFORMAL, OF BELLE FOURCHE SHALE, UNDIVIDED.

Kn NIOBRARA FORMATION. Olive-gray and dark-brownish gray, fissile shale containing abundant thin bentonite beds. Upper half calcareous with a few thin bentonite beds; near top unit contains thin beds of very calcareous, laminated sandstone, siltstone, and sandy limestone. *Inoceramus* prisms common. Upper contact placed at change from calcareous shales to non-calcareous shales of Telegraph Creek Formation (taken from Lopez, 2000). Exposed along southeastern map boundary. Basal contact not exposed; thickness unknown.

MARIAS RIVER FORMATION. Not a mapped unit.

KEVIN MEMBER OF MARIAS RIVER FORMATION. Not a mapped unit.

Kmku UPPER SHALE UNIT, INFORMAL, OF KEVIN MEMBER. Occurs as a nonresistant interval between Eldridge Creek beds (below) and Telegraph Creek Formation (above). Minimally exposed along Currant Creek in NW sec. 31, T. 8 N., R. 22 E., where calcareous and non-calcareous, medium-gray, fissile to blocky shale is observed. Unit is mapped based on topographic expression. Upper contact approximately placed beneath the also unexposed lower shaly part of the Telegraph Creek. Thickness estimated at 130 ft based on well log in sec. 30, T. 6 N., R. 16 E. on West Dome.

Kmke ELDRIDGE CREEK GLAUCONITIC BEDS, INFORMAL, OF KEVIN MEMBER. Glauconitic, micaceous shale, mudstone, and sandstone that weather greenish gray. Sandstones are fine- and medium-grained; predominantly massive and bioturbated; thin, platy trough-cross sets occasionally preserved. Contains prominent resistant, dusky red to dark-orange weathering, calcareous to dolomitic, ferruginous concretions and concretionary beds up to 7 inches thick that are locally fossiliferous. On Womans Pocket Anticline, single large (as much as 3-ft in diameter) concretions are common in the unit, weathering gray to dark-reddish orange, commonly septarian and fractured, with red and white vein filling are also common in the unit. On Shawmut Anticline, concretionary beds dominate the unit throughout; *Scaphites depressus* was collected by W. A. Cobban (2000) on Mud Creek on East Dome. On Womans Pocket Anticline, unit base picked at base of lowest greenish appearing, glauconitic, blocky shale. On Shawmut anticline, along Mud Creek, unit base is placed at base of a 3-ft-thick interval of light gray muddy sandstone with large yellowish gray, fine-grained, quartzose sandstone concretions. This basal quartzose sandstone was not observed on Womans Pocket Anticline. Above this sandstone are 8 ft of greenish gray, glauconitic, micaceous, bioturbated sandstone containing small reddish weathered dolostone concretions. This interval is capped by a laterally continuous ferruginous dolostone concretionary layer containing fossils, chert pebbles and phosphatic pebbles that comprise the MacGowan Concretionary Bed of Cobban and others (1959). Fauna collected from this bed on East Dome by W. A. Cobban (2000) include *Inoceramus sp., crassalella? Sp., Corbula? Sp., Baculites cf. B. asper, Baculites sp., Scaphites sp.,* and small reptilian bone fragments. Thickness of unit estimated at 175 ft based on well log in sec. 30, T. 6 N., R. 16 E. on West Dome.

Kmkl LOWER SHALE UNIT, INFORMAL, OF KEVIN MEMBER. Medium-gray, fissile, commonly soil-forming, poorly vegetated, calcareous to non-calcareous shale with scattered fragments of yellowish white, fibrous calcite plates and pockets of abundant *Inoceramus* fragments. Lower contact with Carlile beds not observed. Unit believed to be continuous upward into non-calcareous, fissile shale exposed below Eldridge Creek beds that contains several bands of whitish gray, calcareous, septarian concretions near contact. *Cremnoceramus crassus* (identified by W. A. Cobban, 1999), a lower Kevin (lower Niobrara) pelecypod, found on Mud Creek on East Dome about 15 ft below Eldridge Creek unit. Currently entire unit is mapped as lower Kevin. Further study may suggest that the lower part should more properly be included with underlying Ferdig Member. Thickness estimated at 200 ft based on well log in sec. 30, T. 6 N., R. 16 E. on West Dome.

Kmf FERDIG MEMBER OF MARIAS RIVER FORMATION. Light-bluish gray weathering, thin (1/4 to 2 inches), micaceous, very evenly laminated and bedded siltstone and very fine-grained sandstone interbedded with very dark gray, clayey shale. Siltstones generally calcareous and have characteristic shiny dark-red iron-oxide coating on bedding-plane surfaces, especially on loose float slabs. Beds commonly burrowed. Two related concretion types characterize unit: (1) fist-sized or larger, egg-shaped to bulbous, soft-gray-brown weathering, calcareous, septarian concretions with dark red calcareous vein filling; (2) large, massive, deep-orange weathering, silty concretions, occasionally septarian, with white vein filling; cone-in-cone structure common and usually fragmented. In some areas these two concretion types seem stratigraphically separated, with the orange type slightly higher in section; elsewhere the two types are found in lateral association and sometimes intergrown. The orange type is the common concretion of the middle Carlile Formation farther northeast (Porter and Wilde, 1993; revised 1999); the first type is new in this part of section. Combined fauna of *Volviceramus involutus, Inoceramus howelli,* and *Prionocyclus hyatti* collected by W. A. Cobban (2000) from thin siltstone beds at two locations on Shawmut Anticline. Thickness estimated at 440 ft based on well log in sec. 30, T. 6 N., R. 16 E. on West Dome.

Kmc CONE MEMBER OF MARIAS RIVER FORMATION. Medium-gray, strongly calcareous, bentonitic shale, weathering light-gray to creamy white; generally deeply weathered and forming soft ground that supports less grass than laterally adjacent units. Contains numerous white, commonly orange-stained, nonswelling bentonites; dense white calcite fragments locally common. Zone of large (1- to 3-ft diameter) light-gray, calcareous concretions, locally septarian, in upper part of member. Includes both Greenhorn Formation mapped to the north and east, and overlying thin interval of calcareous bentonitic beds assigned to very basal Carlile Formation to north and east (Porter and Wilde, 1993; revised 1999). Combined fauna of *Inoceramus fragilis*, *Ostrea* sp., *Scaphites* sp., *Collignoniceras woolgari*, fish bones and fish scales collected by W. A. Cobban (2000) at two locations on Shawmut Anticline. Measured thickness is 104 ft on south flank of East Dome of Shawmut Anticline. Subsurface well log in sec. 30, T. 6 N., R 16 E. indicates a thickness of about 115 ft.

BELLE FOURCHE FORMATION. Not a mapped unit.

Kbfu UPPER SHALE MEMBER, INFORMAL, OF BELLE FOURCHE FORMATION. Dark-gray, medium-gray-weathering, fissile to blocky, non-calcareous shale. A lighter-gray weathering zone of light-gray, fossiliferous limestone concretions occurs about 20 ft above base and locally is overlain by a thin lens of chert-pebble-bearing sandstone. Contact with overlying Cone Member is placed at change from non-calcareous to strongly calcareous shale. *Plesiacanthoceras wyomingense* collected by W. A. Cobban (2000) from base and middle of unit establishes upper Belle Fourche age equivalence. Measured thickness is 50 ft on south flank of East Dome of Shawmut Anticline. Well logs in the Shawmut

Anticline area indicate a greater thickness, up to 170 ft. In areas of steep dip and/or extensive cover, the unit is included within the Big Elk map unit.

Kbfb BIG ELK SANDSTONE MEMBER OF BELLE FOURCHE FORMATION. Light-gray, hard, dense, calcareous to non-calcareous, medium- and fine-grained, chert-rich, “salt-and-pepper” sandstone commonly stained dark red and interbedded with thin, dark-gray to black, clayey shale. Unit occurs as multiple coarsening-upward sequences that are thicker in lower part of member and thinner and possibly discontinuous in upper part. Unit poorly exposed beneath extensive grassy slopes everywhere on Shawmut Anticline; best exposures are in SE/4 NW/4 NW/4 sec. 6, T. 6 N., R. 17 E. on south flank East Dome. Number of sequences in outcrop is uncertain; in subsurface south of the anticline, 1 to 3 sequences are observed in well logs. Individual sequences, where observed, are poorly bedded, burrowed to locally bioturbated sandstone beds 2 to 6 inches thick passing upward into thicker, cross-stratified beds commonly rippled and burrowed at tops and draped with thin, dark, burrowed shale. Some thicker beds are well burrowed throughout; these weather to a mottled light blue-gray with light orange stain. Dark red iron-oxide stain is common along bedding planes and fractures and on broad exposed surfaces. Well-developed ripple bedforms are commonly seen on large float slabs lying on slopes. Black chert pebbles (0.25 to 1.5 inches in diameter) occur in upper few ft of each sequence observed, locally; uppermost sequence, generally thin (5 to 7 ft), is particularly rich in pebbles, and an overlying thin bed encased in shale contains abundant large chert pebbles that often litter ground surface. On north flank of West Dome, northwest flank of Middle Dome (in Timber Creek drainage), and on south flank of East Dome, lower part of unit forms steep parallel ridges and cliff faces above the sandstone bench of upper Mowry Formation. Lower part of each sequence, generally poorly exposed, contains bentonites exposed in white patches across grassy slopes, especially on northwest flank of Middle Dome above Timber Creek. Base of Big Elk presently placed at base grassy slope at consistent white bentonite above an underlying more subdued sandstone rise that is commonly dissected to faceted knobs. Big Elk sandstones are indistinguishable from Mowry Formation sandstones. Thickness of member on East Dome of Shawmut Anticline estimated at 150 ft; well log in sec. 30, T. 6 N., R. 16 E. on south flank of West Dome indicates a thickness of 123 ft. Locally includes overlying thin unit, upper member (informal) of Belle Fourche Formation.

Km MOWRY SHALE. Beds here assigned to the Mowry were first reported by Cobban and Reeside (1960, p. 37-38) who assigned them only to the “unnamed shaly member” of the Colorado Shale. Light-brownish gray weathering, gray, thin- to medium-bedded, fine- and medium-grained sandstone, silty sandstone, interbedded siltstones and claystones, and abundant prominent bentonite beds. Some intervals are highly siliceous and very hard. Base of unit is placed at base of sandstone at contact with underlying dark fissile shale of Shell Creek Member of Thermopolis Shale. Basal sandstone, about 45 ft thick at exposure in sec. 30, T. 7 N., R. 17 E., is composed of four coarsening-upward sequences; generally only upper two are exposed and form single prominent and laterally persistent ridge around Shawmut Anticline. Sandstones are glauconitic, predominantly poorly bedded and strongly burrowed, but cross-stratification locally preserved; tops of beds may be coarse-grained and commonly contain fish debris and black chert pebbles up to 0.5 inch diameter. Burrowed intervals show characteristic light-blue and orange mottling. Upper surface of highest sandstone has well developed wave ripple bedforms often seen in large float slabs on slopes. Above this basal sandstone is a 37-ft thick (50- to 60-ft thick in subsurface) dark, fissile to blocky shale with a medial creamy white, swelling bentonite. Above the shale is a distinctive 12-ft interval of thick white, swelling bentonites with interbedded dark, hard, highly siliceous beds of interlaminated siltstone and dark claystone. These latter beds break into angular blocks that become embedded in the bentonites. This interval forms a discontinuous low ledge of bare-faced, grayish white knolls near bases of slopes. Overlying section largely covered but presumed shaly with thin sandstone and siltstone beds. Uppermost Mowry taken to be a 30-ft thick, gray-brown, soft, thin-bedded, fine-grained sandstone poorly exposed and forming low knolls below the higher topography of the basal Big Elk sandstones. Measured outcrop thickness of formation on West Dome based on data from Reeside and Cobban (1960, p. 37-38) is about 330 ft; a well log in sec. 30, T. 6 N., R. 16 E. on south flank West Dome indicates a thickness of 260 ft.

Lower Cretaceous

Kt THERMOPOLIS SHALE. Composed of dark-gray to black shale, tanish gray sandy shale, olive-tan, laminated, very fine-grained sandstone, and dark-grayish brown, quartzose, medium-grained sandstone; numerous thin bentonite beds throughout. Three members recognized but not mapped separately. Formation generally valley-forming and only moderately well exposed on Shawmut Anticline. **Lower part (Skull Creek Member*)***: composed of very black, fissile, nonresistant shale with numerous thin, iron-stained sandstone laminae in lower part ("Dakota silt" of subsurface). Measured outcrop thickness of formation on West dome of Shawmut anticline is about 215 ft; a well log on south flank of West Dome indicates a thickness of 175 ft**. Middle part (middle sandy member, informal*)*:** up to 4 coarsening-upward sequences forming low continuous to discontinuous ledges of fine- to coarse-grained, bioturbated, sandstone above thick intervals of bioturbated, rubbly weathering, sandy shale and dark gray shale; sandstones locally contain glauconite and abundant fish debris in locally preserved cross-stratified and ripple-laminated beds; black chert pebbles up to 1 inch diameter locally associated with each sequence. The basal sandstone of the interval is 55 ft thick and forms prominent scarp above underlying Skull Creek Shale. Possible *Inoceramus bellvuensis* and *I. comancheanus* collected by W. A. Cobban (2000) just above this sandstone. *I. Nahwisi* collected in higher beds within member by W. A. Cobban (2000). Measured outcrop thickness of member on West Dome of Shawmut Anticline is 261 ft; a well log on south flank of West Dome indicates a thickness of 275 ft. **Upper part (Shell Creek Member*):*** dark-bluish gray-weathering, nonresistant, generally fissile, dark-gray, clayey shale; contains thin white bentonites; poorly exposed. Measured outcrop thickness of member on West Dome of Shawmut Anticline is 53 ft; well logs on south flank of West Dome indicates a thickness of 37 ft. Total Thermopolis Formation thickness on Shawmut Anticline, based on well logs, ranges from about 480 ft to about 625 ft.

NOTE: In comparing the Thermopolis Formation on Shawmut Anticline with the Blackleaf Formation of western Montana (Cobban and others, 1976), the following observations are made by W. A. Cobban (personal communication, 2000): (1) the lowest sandstone of the middle sandy member of the Thermopolis may correlate with the basal sandstone of the Vaughn Member of the Blackleaf, and with the "Belt Butte" sandstone of the Belt, Montana area; (2) the uppermost sandstone in the middle sandy member may correlate with the basal sandstone of the Bootlegger Member of the Blackleaf that includes both the Shell Creek interval and the overlying Mowry interval of the Shawmut Anticline section.

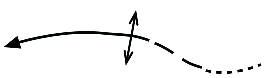
Kfr FALL RIVER SANDSTONE (LOWER CRETACEOUS). Tanish brown weathering, light-grayish tan or yellowish tan, predominantly fine-grained, quartzose sandstone, commonly brown-speckled on fresh surfaces. Cross-stratified and ripple-laminated in thin to thick beds with numerous very thin dark shale partings. Interbedded dark, clayey to sandy shale. Invertebrate tracks and trails on bedding plane surfaces. Exposed in shallow gullies in dip slope on north and southeast flanks of West Dome of Shawmut anticline, and in center of Middle (Devils Pocket) Dome of Shawmut Anticline where base of unit is exposed above Kootenai Formation. Thickness of formation ranges from 90 ft to 105 ft, based on well logs on south flank of Shawmut Anticline.

Kk KOOTENAI FORMATION. Exposures, limited to upper part of formation, are interbedded dark- to medium-red, gray-green, and minor buff-colored silty, blocky weathering mudstone, and yellow and brown, thin-bedded, fine-grained, quartzose sandstones with minor chert and feldspar. Only upper part of unit exposed in quadrangle. Approximate total formation thickness is 285 to 355 ft, taken from well logs on south flank of Shawmut Anticline.

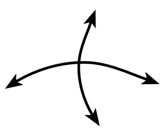
GEOLOGIC MAP SYMBOLS

Contact; dashed where approximately located, dotted where concealed.

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



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



Dome; arrows indicate directions of plunge.

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

Fault with strike-slip motion; dashed where approximately located, dotted where concealed. Arrows indicate relative movement.

Fault; dashed where approximately located, dotted where concealed. Relative motion uncertain.

Strike and dip of bedding; degrees of dip indicated by associated number.

Strike of vertical beds.

Dikes and sills; hachure pattern indicates presence of baked zone in adjacent sedimentary rocks.

Facies change requiring change in nomenclature.

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