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Geology of the Mc Rae Springs Quadrangle, McCone County, Northeastern Montana

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ABSTRACT

Nearly flat-lying Late Cretaceous to early Paleocene rocks, including the upper part of the Bearpaw Shale, the Fox Hills Sandstone and Hell Creek Formation, and lowermost beds of the Tullock Formation, are exposed in the Mc Rae Springs Quadrangle in McCone County, in eastern Montana. Structure in the region is simple, with beds dipping 15–30 feet per mile toward the southeast, off Bowdoin Dome, generally toward the southern Williston Basin.

The upper Bearpaw Shale is largely dark gray to gray-brown marine shales that contain common calcareous concretions with assemblages that range from the *Baculites eliasi* Zone up to the *Baculites grandis* Zone, indicating that these exposed beds are of Lower Maastrichtian age. An upper, light gray-weathering, silty, transition zone separates the darker Bearpaw beds from the overlying Fox Hills Sandstone. Only approximately 100 meters of the upper Bearpaw Shale are exposed in the quadrangle.

The Bearpaw-Fox Hills contact and the Fox Hills-Hell Creek contact were mapped at laterally persistent concretionary sandstone beds at the top and the bottom of the crossbedded, fine-grained, yellowish-gray to dusky yellow Fox Hills Sandstone. Isolated log-like to egg-shaped concretions of limonite-cemented sandstone occur throughout the formation and characterize the formation where it is widely exposed east and west of Montana State Highway 24, which crosses diagonally through the southwestern part of the quadrangle. The Fox Hills Sandstone accumulated in marginal marine to tidal environments. It is of middle Maastrichtian age, and is approximately 40 meters thick in this part of Montana.

The Late Maastrichtian Hell Creek Formation is widely exposed in the southern part of the quadrangle and consists of interbedded, thin, sheet-like sandstones, less extensive lenticular sandstones, and greenish-gray siltstones and mudstones, thin carbonaceous shales, and thin coals. This dinosaur-bearing formation is approximately 62 meters thick where complete sections are exposed in the southeastern part of the quadrangle.

Youngest bedrock units preserved in the quadrangle are basal beds of the lower Paleocene Tullock Formation. They are exposed in isolated outliers in the southeastern corner of the quadrangle and include approximately 20 meters of beds from the formational boundary Z-Coal up to the X-Coal, in units of interbedded shales, claystones, and sandstones, with thin bituminous coals. They are all in the lower part of the Nelson Ranch Member of the Tullock Formation.

Uplands throughout the region are commonly blanketed by a thin veneer of Pleistocene terrace gravels that may locally include glacial erratics over 1 meter in diameter. The terrace gravels characteristically include red and green quartzite, chert, and quartz fragments, and pebbles and cobbles of metamorphic and igneous rocks. Erratics are characteristically coarse-grained igneous and high-rank metamorphic rocks, like

those exposed in the Canadian Shield. The terrace gravels are of lithologies like those exposed in the Belt Mountains to the west, but also may have had a Canadian Shield source.

Flat valley bottoms are blanketed by Quaternary alluvium, locally showing terraces and entrenchment of the streams in the valleys, adjusted to elevations of the Missouri River to the north and west.

INTRODUCTION

LOCATION

The Mc Rae Springs Quadrangle is located in northeastern Montana, southeast of Fort Peck, and east of the Fort Peck Reservoir in western McCone County (Figure 1). The central part of the quadrangle lies approximately 20 miles (30 kilometers) southeast of Fort Peck, and 100 miles (165 kilometers) north of Miles City, Montana. The community of Fort Peck is approximately 14 miles (22 kilometers) southeast of Glasgow, the major shopping center for the region and the closest major source for supplies.'

The quadrangle (Figure 1) lies between 47° 52′ 30″ and 48° 00′ North Latitude and 106° 07′ 30″ to 115° 15′ West Longitude. Montana State Highway 24 crosses diagonally through the southwestern part of the quadrangle. It connects southward to Montana State Highway 200, one of the major east-west highways through the central part of the state, and northward to U.S. Highway 87, which is a major east-west highway across the northern part of the state.

The quadrangle has only moderately low relief (Plate 1), with somewhat step-like topography where "risers" are produced by the relatively resistant Upper Cretaceous Fox Hills Sandstone and somewhat laterally persistent, resistant, sandstones within the Hell Creek Formation (Table 1). Highest relief in the area is in the southeastern part of the quadrangle, where major badland bluffs generally formed on the northern sides of ridges, which rise boldly through upper Hell Creek rocks to small outliers of Tertiary Tullock Formation (Figure 2). The broader steps or slopes between are carved, in large part, on the nonresistant Bearpaw Shale, the oldest rocks exposed in the region, and the more easily eroded mudstones and siltstones of the Hell Creek Formation.

Much of the southwestern half of the region is drained by Bear Creek (Figure 3), which empties westward into Bear Creek Bay, one of the bays along the east shore of Fort Peck Reservoir. The northeastern part drains northeastward from a divide, approximately at Montana Highway 24, into the West Fork of Hungry Creek, Cheer Creek and upper tributaries of Lost Creek, which drains northeastward into Hungry Creek, and ultimately northward into the Missouri River below the Fort Peck Dam.

Elevation in the region ranges from approximately 2100 feet near the Missouri River valley in the northeastern part of the quadrangle, to slightly over 2700 feet in high knobs in the southeastern part. Much of the quadrangle is at an elevation of approximately 2500 feet. Major drainages, like Bear Creek, Hungry Creek, and Lost Creek have flat alluvial plains into which the creeks may be locally steeply entrenched. These flats were locally tilled for grain and forage crops by the local ranchers.

Numerous springs occur in the region, generally associated with thicker sandstone beds that overly impervious clays in the lower part of the Hell Creek Formation or where the Fox Hills Sandstone rests on the Bearpaw Shale (Figure 4). Most of these springs are of small production, but are important elements in the agricultural economy of the grassy prairies.

ACCESS

A moderately intricate net of rustic ranch roads interconnect to somewhat more well defined and traveled county roads, which show on the topographic map of the quadrangle as solid double-lined roads. The ranch roads, developed for local use, provide moderate ready access to the back country of the quadrangle. A few original homesteader log cabins, and second generation cabins, occur throughout the area. However, there are no full time residents within the quadrangle, but rusting remnants of farm machinery are found near many of the springs where isolated ranch homes were early established as homestead bases in the grassy prairies.

FIELDWORK

Field work, mapping, and stratigraphic studies were done during July of 1997, August, 1999, and in June, 2000 as part of continuing investigations of Cretaceous-Tertiary rocks and faunas by Earthwatch and subsequent University of Notre Dame-sponsored research programs, directed by J. K. Rigby Jr. Geologic contacts and other key units were plotted on the 1:24000 topographic maps of the Mc Rae Springs Quadrangle. Final compilation of geologic contacts on a green-line mylar photocopy of the topographic base was completed by tracing from paper copies of the map. Formation contacts and key beds were traced in the field, often using distinctive topographic expressions of the contrasting shale and sandstone sequences or of the coal and bentonitic mudstone sequences throughout the area. A few contacts are locally shown as dashed lines where they were inferred to cross grassland prairies devoid of exposures, or in a few small areas not personally observed

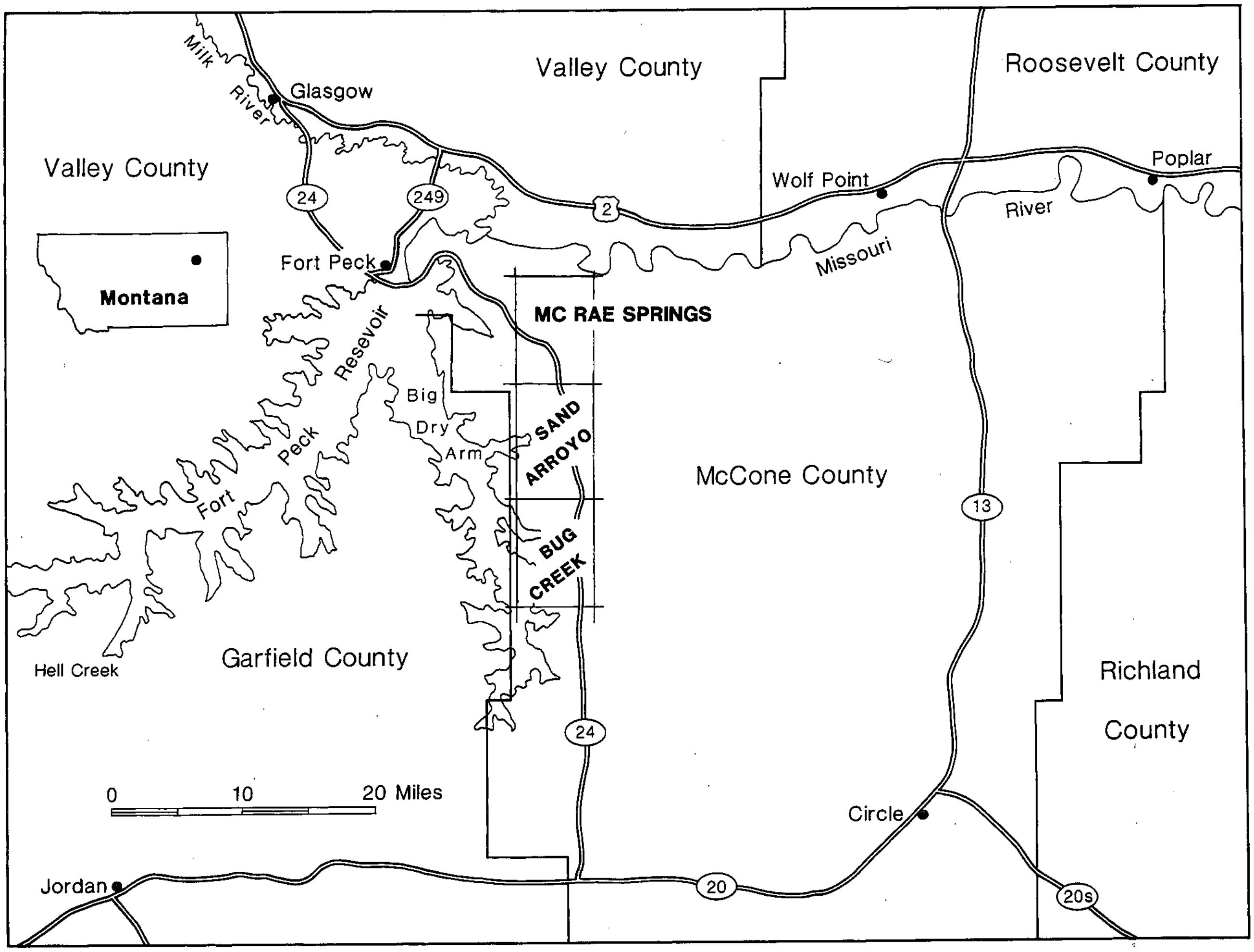


Figure 1. Index map to the Mc Rae Springs Quadrangle, in northwestern McCone County, in northeastern Montana.

in the field by one of us. Stratigraphic sections were measured with the Jacob staff, generally to 0.1 meter accuracy. Xerox copies of aerial photographs of the quadrangle were made available by the regional office of the Agriculture Department Conservation Service in Circle, Montana. Aerial photographs, however, proved less valuable for mapping in the essentially flat-lying beds than the topographic map.

STRATIGRAPHY

Cretaceous System

Montana Group

Bearpaw Shale

Introduction.—Oldest rocks exposed in the Mc Rae Springs Quadrangle (Table 1) are included in the Cretaceous Bearpaw Shale. The dark gray to brownish-gray Bearpaw Shale is part of a widespread Upper Cretaceous clastic sequence that marked the final regression of the Western Interior sea from the Alberta-Saskatchewan-Montana region, and the next to the last major marine transgression from the interior of North America and the Rocky Mountain region (Sloan, 1987). The formation is extensively exposed in the Fort Peck area, in bluffs along the south side of the Missouri River, and in drainages leading into the northeastern part of the Mc Rae Springs Quadrangle (Figure 5). Lower beds and base of the formation are not exposed in the Mc Rae Springs Quadrangle, but the dark shale does crop out beneath the concretionary Fox Hills Sandstone across much of the quadrangle.

The Bearpaw Shale was originally defined by Hatcher and Stanton (1903, p. 211–212) as the concretion-bearing, dark clay shale of marine origin that conformably overlies the Judith River beds and underlies the Fox Hills Sandstone and equivalent units in northern and eastern Montana. The formation has its type locality in the Bearpaw Mountains

Table 1. Stratigraphic sequence of rock units exposed in the Mc Rae Springs Quadrangle, McCone County, northeastern Montana.

AGE			ROCK UNITS	
Quaternary			Recent alluvium and terrace deposits	
			Pleistocene glacial outwash and debris	
Tertiary	Paleocene		Tullock Formation	X-coal
				Z-Coal
Cretaceous	Maestrichtian	Late	Hell Creek Formation	upper
				Barbeque sandstone
				middle
				Gunsight sandstone
		Medial		lower
				Null coal
				lower
		Early	Fox Hills Sandstone	
			Bearpaw Shale	base not exposed

of central Montana, but has been recognized extensively in northern, eastern, and southern Montana and in the Elk Basin region of southern Alberta and northern Montana.

Collier and Knecktel (1939, p. 9) observed that the upper contact with the Fox Hills Sandstone is gradational and marked by a general increase in sand upward within the transition zone. They noted that the Bearpaw Shale is approximately 300 meters thick in eastern Montana. Later, Jensen and Varnes (1964, p. F5) observed that in the Fort Peck area the Bearpaw Shale area is 348 meters thick. In the Mc Rae Springs Quadrangle only the upper approximately 100 meters of the formation is exposed in the northeastern part of the quadrangle and even less than that in southwestern areas.

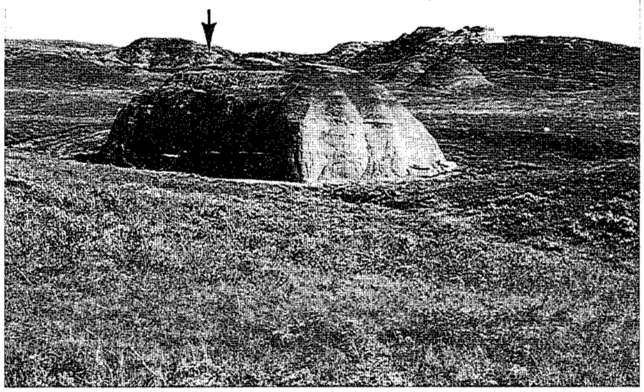


Figure 2. View southeastward to darkly shadowed Combine Butte, in the central part of Sec. 22, T. 25 N., R. 43 E., which is held up by lower massive sandstones and carbonaceous bentonitic mudstones of the lower Hell Creek beds. High points in the background are capped by lower beds of the Tullock Formation and extend up from the Z-Coal indicated by the arrow in the left center. Those outcrops are in the northern part of Section 26, on the divide between Widow Coulee, in the foreground, and Bear Creek to the south of the ridge.

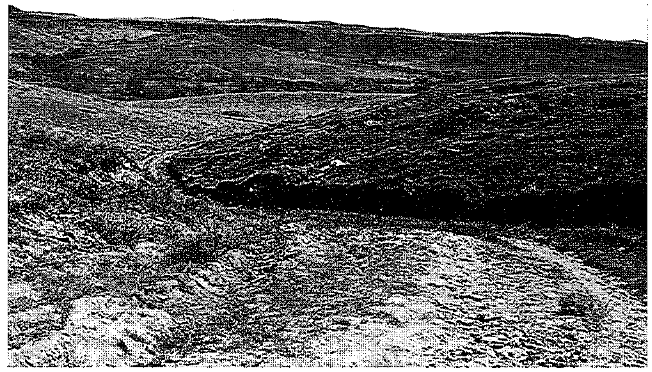


Figure 3. View northward along the ranch road across Bear Creek, from the center of Sec. 24, T. 25 N., R. 42 E. Bear Creek is marked by the line of trees in the valley floor. Costello Coulee is the tree-lined tributary to Bear Creek on the left. Concretionary Fox Hills Sandstone is exposed in the road and in rough exposures on either side of the road in the foreground and capping the hills beyond Bear Creek. High hills on the skyline are near Montana State Highway 24 and are held up by lower beds of the Hell Creek Formation. Coal Hill is the high point on the skyline near the left margin.

Lovering and others (1932, p. 702–703) also observed that the contact between the Bearpaw Shale and overlying Fox Hills Sandstone is somewhat gradational. They defined the top of the Bearpaw Shale at the base of the dominant buff and brown sandstones and at the top of the gray marine clay shale and sandy shales. We have generally utilized that same boundary and have mapped the contact at the base of the lowest ledge-forming, concretionary yellow-gray sandstones of the Fox Hills Sandstone throughout the quadrangle.

In the eastern part of the quadrangle there is a transitional unit that appears very light yellow gray beneath the concretionary Fox Hill beds and above the darker marine clay shales that are more characteristic of the lower part of the formation (Figure 6). That transitional sequence is approximately 12 meters thick, at its thickest, where extensively exposed in section 3, T. 25 N., R. 43 E., beneath outliers of the basal Fox Hills Sandstone in hills between the junction of Cheer Creek and the West Fork of Hungry Creek. It is Unit 4 of the Poplar Anticline section of Reiskind (1975), and may be a facies equivalent to the Colgate Member of the Fox Hills Formation as exposed at Glendive, Montana (R. Sloan, personal communication, 2001)

The light yellow-gray transitional unit is also exposed in promontories to the west, in headwaters of the West Fork of Hungry Creek, but it is thinner there. The light gray transition is not exposed in the limited northwesternmost or southwesternmost, commonly grass-covered, outcrops in the quadrangle.

Outcrop Area and Topographic Expression.—Throughout the area underlain by the Bearpaw Shale, the formation has been carved into intricate badlands and irregular grassy prairies. No well exposed complete section of the beds occurs in the quadrangle, but the dark shale crops out in numerous low escarpments, meander bends, and barren hills throughout the area. The formation is the principal outcrop unit in the northeastern part of the quadrangle, but is also moderately well exposed in the southwestern part of the quadrangle along Bear Creek, east of Bear Creek Bay in the Fort Peck Reservoir area. Because of the ease of erosion of the shale, it tends to form smooth hills and low grass-covered slopes, except where exposed in limited badlands, particularly in the northeastern part of the quadrangle. Only the upper 20–25 meters of the formation is exposed in lower Bear Creek bluffs beneath the concretionary Fox Hills Sandstone in the southwestern part of the quadrangle. Those exposures extend up drainages to small springs or seeps that form at the top of the impervious Bearpaw Shale and base of the porous Fox Hills Sandstone in many of the tributaries. Similar springs are developed in headwaters of many of the small gullies that drain the northeastern part of the

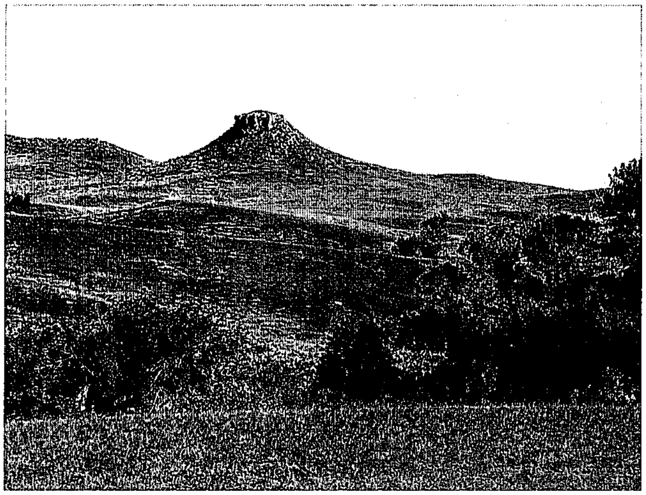


Figure 4. View northward to Caprock Butte, in the north-central part of Sec. 6, T. 25 N., R. 43 E., looking across the spring-watered, tree-lined, headwaters of Bridge Coulee in the central part of Sec. 26. Caprock Butte is held up by the basal Hell Creek Sandstones above the more slope-forming Fox Hills Sandstone. Springs in the foreground are characteristic contact springs formed at the base of the porous sandstones of the Fox Hills Sandstone and the top of the impervious Bearpaw Shale.

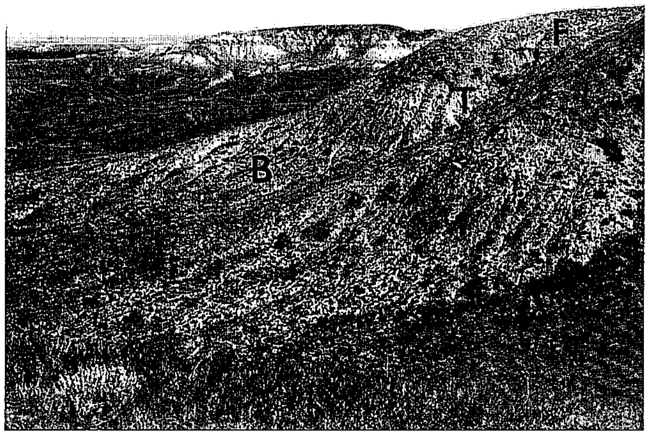


Figure 5. View northward from the east-central part of Sec. 21, T. 26 N., R. 43 E., showing the upper part of the dark Bearpaw Shale in the low outcrops on the left (B), overlain by the light shaly transition zone (T) prominently exposed in the central part of the photograph. These light slope-forming beds are overlain by the Fox Hills Sandstone (F) that produces the concretionary low ledgy zone in the foreground and caps the promontory and ridge in the near distance. The dark tree-covered valley of the Missouri River, in the background, is beyond the northern edge of the quadrangle.

quadrangle, as well. Mc Rae Springs, for example, is a contact spring near the top of the Bearpaw Shale and base of the Fox Hills Sandstone. These springs are important economic resources in the grassland-prairie ranching economy of the region.

Best exposures of the Bearpaw Shale are perhaps those in tributaries to Hungry Creek (Figure 7) and Lost Creek in the north-central part of the quadrangle, generally beneath the Fox Hills outlier south and west of Bone Bluff, in the northeastern part of Section 21 T. 26 N., R. 43 E. (Figure 5). This is also the thickest sequence of Bearpaw Shale exposed in the quadrangle.

Lithology.—The Bearpaw Shale is a moderately uniform, dark gray to medium gray, clay shale throughout the quadrangle. Several horizons of moderately large, fossiliferous, calcareous concretions occur in isolated exposures throughout the outcrop band, but are particularly prominent in outcrops east of the reservoir along Cheer Creek, in the western part of Section 2, T. 25 N., R. 43 E., and along the access road to Bone Bluff triangulation station in the north-central part of Section 22, T. 26 N., R. 43 E. The concretions are commonly dark gray, micritic-appearing, limestone. Most are septarian and weather into angular fragments on the slopes. Concretions range up to approximately 1 meter in diameter as flattened obloids, but more common concretions are only 0.1–0.2 meters in diameter or smaller. Many of these concretions contain abundant ammonites and bivalves, but the fossils are commonly difficult to collect because the concretions shatter in such irregular fashion. Reiskind (1975, Figure 2) reported that these concretion layers range upward from the *Hopoloparia* lobster concretionary layer, through the *Baculites eliasi* concretionary layer, the *Baculites baculus* concretionary layer, the *Protocardia* concretionary layer, and the *Baculites grandis* concretionary layer in the Poplar Anticline area, which would include part of the McRae Springs quadrangle. Slopes are locally littered with angular fragments of the concretions and are locally associated with obvious residual pebbles from overlying terrace gravels of Quaternary age.

Scattered small selenite gypsum crystals occur throughout the sequence, but are most common in upper clay shales beneath the silty transition beds near the top of the formation.

The upper few meters of the Bearpaw Shale in the transition beds are consistently lighter gray to medium gray-brown and weather very light-gray to light yellowish-gray. The transition unit forms a prominent distinct light band visible even from a distance in northeastern parts of the quadrangle. Yellowish-gray silty sandstone occurs interbedded with clay shales of lighter gray tones in the upper part in the gradational sequence. These upper beds lack concretions and commonly form light slopes in the contact zone.

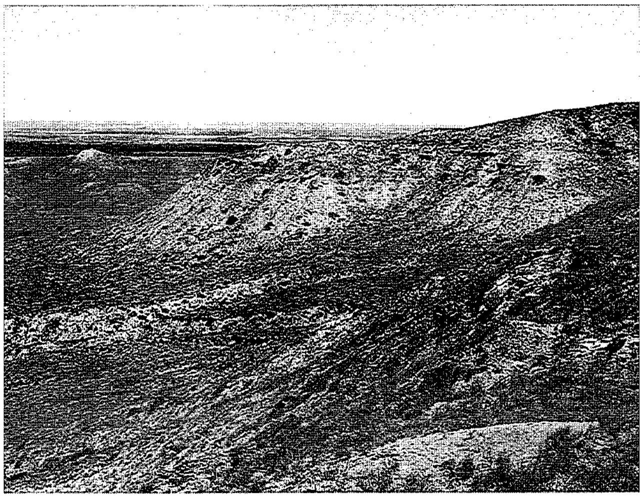


Figure 6. View northward from the south-central part of Sec. 21, T. 26 N., R. 43 E., showing the light slope formed on the transition beds at the top of the Bearpaw Shale largely obscured by debris, in the intermediate distance, but forming prominent light slope zones below the darker, overlying, ledgy Fox Hills Sandstone that erodes to form the rough exposures on the right and caps the outlier in the distance. The Missouri River valley in the background is indicated by the dark trees on the left.

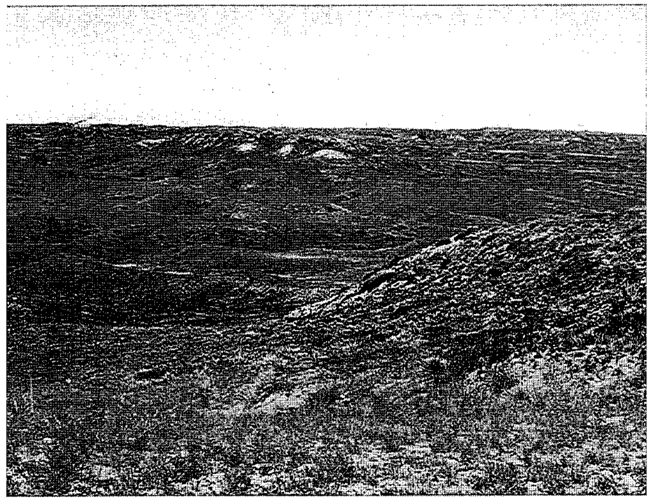


Figure 7. View toward the northwest over Hungry Creek Pass, carved in poor exposures of the upper Bearpaw Shale, to an outlier of dark lower Fox Hills Sandstone above the light transition beds in the distance, in the west-central part of Sec. 29, T. 26 N., R. 43 E., as seen from the southeastern part of Sec. 29. Concretionary beds in the foreground are of the lower part of the Fox Hills Sandstone, above beds of the transition zone.

Fossils and Age.—Marine fossils are moderately common throughout the exposed Bearpaw sequence, but all of the fossils observed by us occurred in concretions, where on many of the ammonites and on some of the *Inoceramus* oysters the original mother-of-pearl nacreous layer is still intact. All of the ammonites recovered by us are *Baculites grandis* from the upper part of the formation. These beds are of lower Maastrichtian age. Reiskind (1975) reported the occurrence of fossils characteristic of the older *Baculites eliasi* and *Baculites baculus* Zones in lower Bearpaw Shale beds in the Poplar Anticline area, which includes the northeastern part of the Mc Rae Springs quadrangle. Obradovich and Cobban (1975, p. 36) put the base of the Maastrichtian two ammonite zones below the *Baculites eliasi* Zone. Thus the Bearpaw Shale beds exposed in the Mc Rae Springs quadrangle are all of lower Maastrichtian age. They are laterally continuous and part of the major fine-grained terrigenous clastic sequence equal to the upper Pierre Shale of the Dakotas (Cobban and Reeside, 1952).

Thickness.—Full thickness of the Bearpaw Shale is not exposed in the Mc Rae Springs Quadrangle. Thickest exposed sections there are approximately 100 meters (300 feet) thick, and are exposed above the alluvial fill of the valleys and below the overlying Fox Hills Sandstone in Sections 21, 22, 27, and 28 of T. 26 N., R. 43 E., in the vicinity of Bone Bluff triangulation station, and to the west and southeast.

Fox Hills Sandstone
(Montana Group)

Introduction.—Meek and Hayden (1862, p. 419, 427) named the Upper Cretaceous Fox Hills Sandstone for yellowish gray and gray sandstone and sandy clays that occur above the dark gray shales, which are now known as the Pierre Shale in the Dakotas and the Bearpaw Shale in eastern and north-central Montana, and below the gray non-marine clays and yellowish sandstones of the "Fort Union Formation," the lower part of which is now included in the Hell Creek Formation. They named the formation for exposures on Fox Ridge in northwestern South Dakota, 550 miles (884 kilometers) southeast of Fort Peck. The name, however, has been widely used throughout the northern Rocky Mountains and the northern plains for a regressive, marginal marine, sandstone at the western margin of the Cretaceous Interior Seaway.

Lovering and others (1932, p. 702–703) defined the base of the formation as a transition from the gray marine clays and clay shales of the Pierre Formation, below the base of the dominant yellowish-gray concretionary sandstones of the Fox Hills Sandstone. They placed the top of the Fox Hill Sandstone where that lithologic unit grades upward into predominantly fresh or brackish water, lighter gray-brown, sandstones and bentonitic claystones that are occasionally accompanied by coal or lignitic shale of the Hell Creek Formation. Thom and Dobbin (1924, p. 490) assigned the upper very light-gray sandstone to the Colgate Sandstone, a member of the Fox Hills Formation.

Collier and Knechtel (1939, p. 9–10) followed that usage, as did Brown (1914), who recognized the Colgate member of the Fox Hills Sandstone and an underlying marine Fox Hills Sandstone as an unnamed member. Stevenson (1947) concluded that the formation in the McIntosh quadrangle in South Dakota consists in ascending order of the Trail City, Timber Lake, Bullhead, and Colgate Members. Waage (1961) studied the Fox Hills Formation in the type area and continued the subdivision of the formation into several members.

Collier and Knechtel (1939, p. 10), in their study of the coal resources of McCone County, made no attempt to separate members of the Fox Hills Sandstone, although they did suggest that the Colgate Member is present in McCone County. Jensen and Varnes (1964, p. F11–F16) later described the geology of the Fort Peck area and concluded that the light gray sandstone of the Colgate Member is not distinguishable in northern McCone County, northeast of Hell Creek, which is approximately 40 miles southwest of the Mc Rae Springs area. Bell (1965) in his regional study concluded that the Bullhead Member of Waage is the upper fine-grained sandstone and interbedded gray sandy shale that he could recognize through much of McCone County. Bell (1965) reported that the member may be as much as 10 meters thick in the Sand Arroyo Quadrangle, just south of the Mc Rae Springs area.

We have not differentiated members within the Fox Hills Formation in the McRae Springs area, but have mapped the formation as a single unit.

Outcrop Area and Topographic Expression.—The Fox Hills Sandstone is broadly exposed in upper tributaries and in the drainage divide region between Bear Creek in the southwestern, and Hungry Creek and Lost Creek in the northeastern parts of the quadrangle (Figures 6, 7). Fox Hills beds cap the ridges extending out from the drainage divide. The formation is the most areal extensively exposed unit in the quadrangle. Exposures extend from the high outlier of the formation at Bone Bluff, southeastward along the divide between Lost Creek and the West Fork of Hungry Creek, to the extensive outcrops in parallel bands northeast and southwest of the drainage divide through the central part of the quadrangle.

Although outcrop areas are extensive and the formation is widespread in the quadrangle, no complete sections of the formation are exposed. Rather, laterally continuous ledges of sandstone concretions form lower and upper outcrops (Figures 5–7) and are separated by a broad slope zone of poor exposures. Sandstone units crop out discontinuously throughout the region where blowouts, slumps, or steeply undercut banks of drainages locally expose the soft, nearly unconsolidated sedimentary units typical of the formation. Excellent exposures of the upper part of the unit, however, occur in road cuts along Montana State Highway 24, in the northern part of Section 12, T. 23 N., R. 42 E., in the western part of the quadrangle, and in road cuts along the highway northwestward beyond the quadrangle. There characteristic limonite-cemented calcareous concretions, which as so common in both the upper and lower ledgy parts of the formation, occur in the soft, yellow-gray to orange-gray-weathering, cross-bedded sandstones. Elsewhere, similar exposures occur as isolated barren lands or as slumped-appearing, sprawling conifer-covered, outcrops on northern slopes in some of the steeper topography. Lower cross-bedded concretionary sandstones are also well exposed in road cuts along Montana State Highway 24, immediately northwest of the quadrangle.

Contacts.—Basal and upper contacts of the Fox Hills Sandstone have been drawn at the base of the lowermost and at the top of the uppermost, cross-bedded, concretionary, ledge-forming sandstones of the formation.

Lithology.—The Fox Hills Sandstone in the Mc Rae Springs area consists of upper and lower ledge-forming sandstone units, 10 m or more thick, separated by a middle more slope-forming unit of less well-cemented sandstone and minor interbedded gray mudstone. Sandstones of the formation are commonly only moderately cemented, but consistently crossbedded, very fine-grained to fine-grained, and medium to well sorted. They are generally yellowish-gray to dusky yellow and weather yellowish-gray in irregularly, poorly cemented units. In more resistant concretionary units, the sandstone may be dusky yellow to grayish-orange, or dark yellowish-orange. Most ledgy exposures of the upper and lower units appear massive, without shaly partings, although all are irregularly crossbedded, moderately to well-sorted sandstone. Small lenses of rip-up clasts of lighter gray siltstones or claystones occur between crossbed sets or as platy elements in layers on cross-bed surfaces throughout the formation, and show particularly well in highway cuts in the western part of the quadrangle where details of sedimentary structure are best displayed.

Large egg-shaped to log-like concretions occur throughout the area and may occur in distinct layers, as well shown in road cuts of the upper sandstone in Section 12, T. 25 N., R. 42 E., Montana Highway 24. The concretionary resistant units (Figure 6) were noted by Jensen and Varnes (1964, p. 16), who observed that they "form the intricately eroded rimrock that is a conspicuous feature of the Fox Hills Sandstone in this area." These concretions are commonly 2 or 3 meters long and a meter or less thick, or in diameter, although some 10–15 m long are well exposed in highway road cuts. They have dense limonite-cemented cores, but less cemented spheroidal layered weathering in the outer yellowish-gray rinds, which are also calcareous. Elongate concretions are commonly parallel to crossbed directions in the direction of paleoflow, although those in the upper part of the formation exposed in the north-central part of Section 12, are locally essentially at right angles to crossbed directions.

Crossbed sets or troughs within sandstones of the formation are commonly one meter or less high, and generally indicate sediment transport toward the south and east. However, in excellent road cut exposures in both the upper and lower sandstones along Montana Highway 24, opposed northeast and southwest transport directions in trough cross-bed sets indicate deposition under tidal conditions.

Channel fills or trough cross-bed sets in the upper sandstone are commonly only 2 m or less wide and to 0.5 m deep. Most of the more planar cross-bed sets are in units 30–40 cm thick in the same area. Stratification is often clearly defined by aligned flat pebbles or carbonate- or limonite-cemented concretions.

Details of the internal structure of the lower sandstone are evident in road cut exposures at approximately mile 46.3 on Montana Highway 24, a short distance beyond the quadrangle boundary to the northwest. The lower part of that exposure is of poorly cemented sandstone with low-angle cross-stratification indicating current flow toward the east in nearly every set. These sets range from 10 cm up to 30 cm thick and are composed of only moderately sorted sand in which ferromagnesian minerals and black and green chert are common. Up section, cross-bed sets are thicker and also indicate dominant flow toward the east or northeast. A few trough deposits are preserved and also show currents flowed to the northeast. This relatively uniform section is cut by a major channel approximately 3 m deep. That channel is filled with numerous small cross-bed sets, each only a few cm thick and each showing direction of transport of the more quartzose sand toward the northeast.

A small silicified and limonite-stained log, approximately 20 cm in diameter and one-half meter long, was found in the channel fill. It was lying parallel to stratification on one of the thicker cross-bed sets. Other silicified fragments, limonite concretions, and limonite-replaced rip-up clasts also occur in the same section.

Some sandstones, where well exposed, show trains of crossbed sets, like those described by Rigby and Rigby (1990) from the Annabelle Beach region in the Bug Creek Quadrangle to the south. Some show remarkable uniformity in rhythmically bedded crossbed where laminae are 1 to 2 centimeters thick in the steeply sloping, laterally stacked, barchanoid linear structures. There are no major exposures of bedding type outcrops in the Mc Rae Springs quadrangle that would allow studies like those done in the Annabelle Beach region along the shore of Fort Peck Reservoir (Rigby and Rigby, 1990).

The middle part of the formation is poorly exposed over much of the quadrangle, probably because it is composed of virtually uncemented light gray to yellow-gray sandstone and interlensing dark to medium gray bentonitic mudstone.

Age.—Gill and Cobban (1973) concluded that the Fox Hills Sandstone in central Montana is probably of lower Maastrichtian age. It is probably of middle Maastrichtian age (*Baculites grandis* Zone or younger) in this part of Montana (Sloan and others, 1986). We collected no fossils from the Fox Hills Sandstone in the Mc Rae Springs area, other than fragments of a silicified log, so we cannot add additional information on the age of the unit.

Thickness.—The Fox Hills Sandstone, as mapped, is 35–40 meters thick in the Bear Creek area in the southwestern part of the quadrangle. It is approximately 40 meters thick in the Mc Rae Springs area in the northwestern part of the quadrangle and in the Alexander Springs area in the east-central part of the quadrangle. It appears to be relatively uniform in thickness across the quadrangle, as mapped. If the additional 10–12 meters of transition beds included in the upper Bearpaw Shale, in the northeastern part of the quadrangle, were added the formation would thicken in that direction.

Post-Montana Group Formations

Hell Creek Formation

Introduction.—Brown (1907, p. 829–835) differentiated the Hell Creek beds as fossiliferous freshwater deposits that occur above the Fox Hills Sandstone in the western part of then Dawson County, now in part Garfield County, Montana. Hell Creek, in Garfield County, is the type locality for the formation where it is extensively exposed, there and on nearby tributaries of the Missouri River.

Later, Collier and Knechtel (1939, p.10–11) in their McCone County report discussed the Hell Creek Member of the Lance Formation where it is exposed along Dry Creek. They included the Lance Formation in the Eocene (?) series, but observed in a foot note, that after the report was written, the Hell Creek and Tullock Members, as they recognized them, were raised to formation rank, and the U.S. Geological Survey put the Hell Creek beds in the Cretaceous and the overlying Tullock Formation in the Cretaceous or Eocene. Frye (1969, p. 3–16) summarized development of stratigraphic nomenclature of the Hell Creek beds.

Brown (1938) placed the Cretaceous-Tertiary boundary between the Hell Creek and Fort Union Tullock beds at the approximate stratigraphic position where it is placed today, based on his work with the fossil plants. Discussion of the exact stratigraphic position of the boundary continued through the 1960's to the 1980's, with renewed emphasis following the debate on a possible catastrophic extinction of the dinosaurs related to a meteorite impact. The iridium anomaly layer, presumably from that supposed impact, has been mapped near the traditional Cretaceous-Tertiary boundary, in areas to the south. It is a thin carbonaceous sandstone and clay that shows marked enrichment in iridium (Nichols and others, 1986; Orth and others, 1981; Orth *in* Sloan and others, 1986; Smit and others, 1987; Tschudy and others, 1984; and Rigby and Rigby, 1990). Those boundary rocks are exposed on isolated outliers in the southeastern part of the quadrangle, a few meters below the formational Z-Coal, that we have mapped as the base of the Tullock Formation and top of the Hell Creek Formation, which is the Z-Coal of Collier and Knechtel (1939).

Contacts.—The base of the Hell Creek Formation has been mapped at the base of the generally muddy or clay-rich beds of the formation, or below a non-resistant light green-gray sandstone that overlies the ledge-forming, yellow-gray, concretionary sandstones of the Fox Hills Formation (Figure 2). The formational contact at the top of the Hell Creek Formation and base of the Tullock Formation has been mapped at the formational Z-Coal (Figure 2), as utilized by Rigby and Rigby (1990) in the Bug Creek and Sand Arroyo quadrangles to the south. It is the lowest prominent coal zone in the contact zone, although two or three additional carbonaceous shales, or very thin coals, appear in the same general unit. We have selected the most prominent and thickest, most continuous, one as the boundary Z-Coal. This may result in a few meters of Tertiary beds actually being included within the Hell Creek Formation as we have mapped it, following along the pattern of Rigby and Rigby (1990). The lower carbonaceous shale and thin streaky bituminous shale of the lower Z-Coal associated with the iridium event has been recognized in good exposures. A shift of the contact to this less certainly identifiable and less evident topographic break would result in only minor differences from that shown on the accompanying geologic map (Plate 1).

The Hell Creek Formation has been subdivided into informal members, with lower and middle members separated by the moderately persistent Gunsight Butte sandstone, and middle and upper members separated by the similarly moderately persistent Barbeque sandstone (Plate 1).

Outcrop Area.—The Hell Creek Formation is broadly exposed in the south half of the quadrangle (Plate 1). It generally forms uplands along the divide between Bear Creek, in the southwestern part of the quadrangle, and the major drainages of Lost Creek and Hungry Creek in the northeastern part of the quadrangle. The formation is also exposed locally in badland exposures in the southern part of the map (Figure 8), generally on the divide between Bear Creek and headwaters of streams draining southward into Sand Arroyo. Most extensive exposures of the formation are in the bold badland bluffs beneath outliers of the Tullock Formation in the northern part of Sections 26 and 27 of T. 25 N., R. 43 E., in hills north of the headwaters of Bear Creek and east of Montana Highway 24 (Figures 2, 9). Dinosaur-bearing sandstones (Roberts, 1998) and underlying mudstone and claystone beds are also well exposed in the west-central part of Section 22, T. 25 N., R. 43 E. (Figure 10).

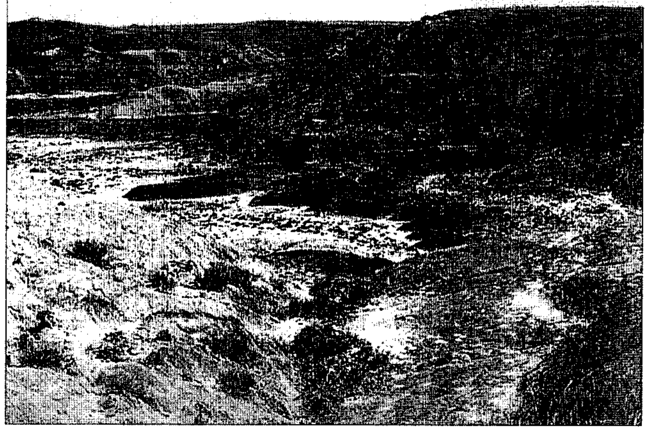


Figure 8. Badland exposures of the lower Hell Creek Formation Nelson Ranch Member, as seen eastward from the southeast corner of Sec. 30, T. 25 N., R. 43 E. The Gunsight Butte sandstone, or the Number 3 Sandstone as that term was utilized in the San Arroyo Quadrangle to the south (Rigby and Rigby, 1990), caps the near exposures. Bentonitic claystones and mudstones form the light outcrops in the foreground.

The Hell Creek Formation commonly forms flat-topped uplands or holds up small buttes, such as Gunsight Butte, in the southeast part of Section 7, T. 25 N., R. 43 E. Sandstones in the formation form broad, easily mapped shoulders in the badlands and provide key stratigraphic units for mapping.

Small, steep, intricately-carved badland exposures are developed on interbedded bentonitic mudstones and claystones where the protecting remnants of sandstone have been removed by erosion. Such mammillary-shaped outliers are well developed in Sections 22 and 27, in the drainage divide area in the southeastern part of the quadrangle.

Lithology.—The Hell Creek Formation in the Mc Rae Springs Quadrangle consists of interbedded mudstones, claystones, and carbonaceous shales, separated into major units by laterally persistent sandstones (Figure 11, Plate 1). The Hell Creek beds were commonly referred to as the "somber beds" in the early literature, because of their generally gray appearance, in contrast to that of the underlying yellowish-gray and buff Fox Hills Sandstones

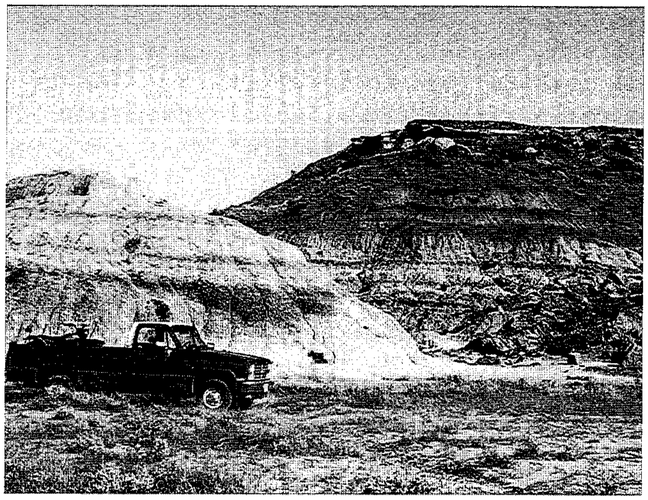


Figure 9. Lower Hell Creek beds in badland exposures in the southeastern part of Sec. 22, T. 25 N., R. 43 E. The Gunsight Butte sandstone caps the ridge on the right, above the carbonaceous shale triplet of the Null-Coal zone in the lower part of the Hell Creek Formation. Bentonitic claystones and carbonaceous shales alternate in the badlands and domal outlier of the lower beds.

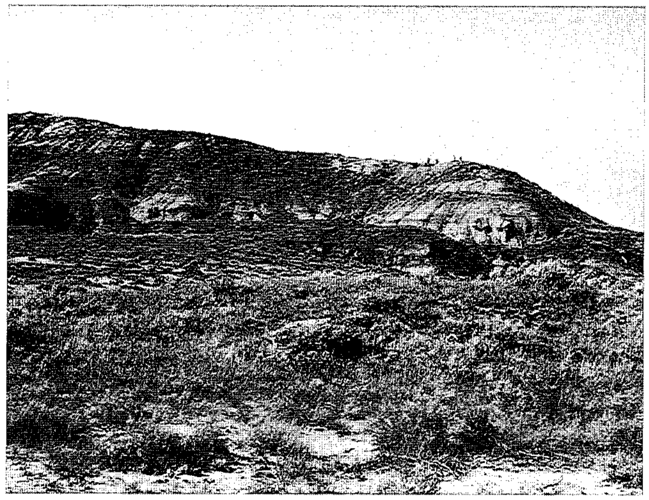


Figure 10. View northward to the prominent ridge and the Barbeque Quarry dinosaur locality, indicated by figures on the skyline. The Gunsight Butte sandstone forms the ragged ledges near the base of the escarpment and the Barbeque Quarry sandstone forms the light band in exposures left of the quarry, which is in the west-central part of Sec. 22, T. 25 N., R. 43 E.

and the overlying more yellowish-gray banded Tullock Formation. Sandstones of the Hell Creek Formation occur in relatively laterally continuous thin sheets or in elongate channel-fill lenses. These sheet sandstones are characteristically fine-grained to medium-grained, and are commonly crossbedded and ripple marked. They appear like salt-and-pepper sandstones, because they contain moderate quantities of fragments of dark, ferromagnesian minerals and dark chert intermixed with the dominant coarse quartz sand. Two of these sandstones have been mapped as informal subdivisions of the formation (Plate 1) in southern and southwestern parts of the quadrangle.. The lower of these (Figure 11) is termed the Gunsight Butte sandstone, for exposures on that distinctive outlier west of the highway, in the southwestern part of Section 1, T. 25 N., R. 42 E., in the western-central part of the quadrangle. What we have mapped as the Gunsight Butte sandstone in the southwestern part of the quadrangle is considered to be equivalent to the Number 3 sandstone of the Hell Creek Formation as mapped by Rigby and Rigby (1990) in the Sand Arroyo quadrangle, adjacent on the south. The upper laterally persistent sandstone in the Mc Rae Springs quadrangle is termed the Barbeque sandstone because it is well exposed in and near the Barbeque dinosaur quarry, in the west-central part of Section 22, T. 25 N., R. 43 E., in the southeastern part of the quadrangle. This sandstone, as we have mapped it in the southwestern part of the quadrangle, is considered to be equivalent to the Number 4 sandstone of the Hell Creek Formation of the Sand Arroyo quadrangle, to the south, as mapped by Rigby and Rigby (1990).

Bell (1965, p. 82–88) studied heavy mineral compositions of 10 samples from the Hell Creek Sandstone and noted the most common grains are magnetite, ilmenite, and limonite followed by biotite, chlorite, muscovite, zircon, apatite, epidote, and tourmaline. He concluded the sands were apparently derived from volcanic terrains to the west or northwest.

Most sandstone lenses within the formation range from light olive-drab to light yellow-gray. Most have high clay content, generally with little cement except where concretionary units are cemented by limonite or calcite. There the rocks range from medium yellow-gray to dark yellow-brown, depending upon the concentration of limonite in the cement.

Because the concretionary units are the most firmly cemented, they commonly form cap rocks or basal units to the more easily eroded sandstones (Figure 9). Less-well cemented sandstones commonly form rounded hills or gentle slopes, except where protected in steep areas by the overlying concretionary units. There they commonly form almost vertical walls beneath the protecting lithified layers. Where the protecting layers have been removed, the sandstones weather and erode away moderately quickly.

Lenticular sandstones commonly contain clay-pebble units. These have been associated with fossil small-vertebrate localities (Rigby, 1987) and the clasts generally are of rip-up origin and of local derivation.

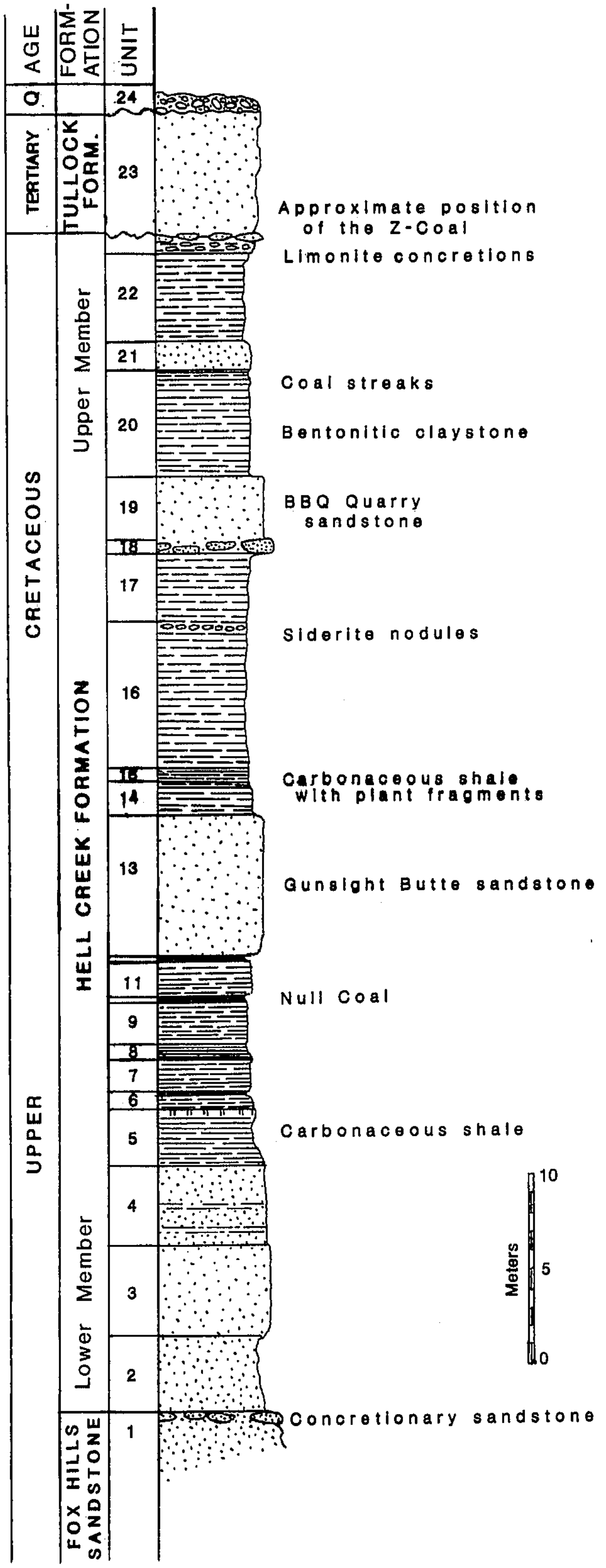


Figure 11. Stratigraphic section through the Hell Creek Formation exposed north of the Barbeque Quarry, in the south part of the northwest quarter of Sec. 22, T. 25 N., R. 43 E., beginning in the headwaters of Widow Coulee, near the center of Sec. 22 and continuing westward to the high point with a spot height of 2690 feet.

Moderately massive sandstones mapped as the basal unit of the formation in southern and southeastern parts of the quadrangle appear relatively uncemented and have much the same mineral composition as the underlying Fox Hills Sandstone. Where well exposed, for example in the small hill immediately west of the center of Section 22, T. 25 N., R. 43 E. in the headwaters of Widow Coulee (Figure 2), the relatively uncemented sandstone forms vertical walls protected in part by thin concretionary sandstones or by the cap of gray sandy mudstone. They rest on the uppermost concretionary sandstone layer of the Fox Hills Sandstone, which is commonly yellowish-gray to dusty yellow or grayish-orange to dark yellowish-orange in weathered exposures. Above those basal units, the sandstones are light olive-drab to light yellow-gray and appear much like sandstones from the middle part of the Hell Creek Formation, such as those exposed in vertical bluffs to the west and southwest in the west-central part of Section 22 and into the east-central part of Section 21 of T. 25 N., R 43 W. Most of these sandstones contain isolated carbonaceous fragments and are of non-marine origin.

It is because of the contrast in color and structure, and similarity with sandstones higher in the formation, that this lower transition unit has been placed in the Hell Creek Sandstone. In addition, the underlying yellowish concretionary bands form a more consistent mappable horizon than the poorly and rarely exposed basal claystones of the Hell Creek beds across the rounded grass covered prairies.

Much of the Hell Creek Formation is composed of siltstones and mudstones that weather to form rounded "popcorn" surfaces where they are bentonitic (Figure 9). Most of the fine clastic units appear pale olive-gray or light olive-gray to olive gray-green and weather light gray. Some units are light to medium yellow-gray, particularly those associated and laterally equivalent to some of the lenticular sandstones. They form massive-appearing beds that are routinely fine grained and commonly darken upward into carbonaceous shales that contain fragments of fossil leaves or "coffee grounds" of plant debris. Some of the massive units appear virtually unbedded, but others with silty partings are well bedded and weather to flakes and irregular debris.

Some of the claystones contain dark brown to reddish-brown siderite nodules and form somewhat purplishappearing units. Carbonaceous shales in the formation range from light gray-brown to dark gray and coally, with shiny bituminous-appearing partings in the more organic-rich units, like that associated in the sequence with the Null-Coal in the lower part of the formation (Figure 9). Where plant debris is abundant, these units weather to dark gray or dull black powdery slopes, and where less abundant to reddish brown or purplish zones.

The Null-Coal is part of the triplet of carbonaceous shale and coal (Figure 9) that occurs approximately 22 meters above the base of the formation, as we have mapped it in the west-central part of the quadrangle in Coal Hill and surrounding areas. That coal is approximately 0.3 meters thick and consists of approximately half brown and dark gray carbonaceous shale and shiny vitrinite bituminous-appearing coal. It is a laterally persistent unit in the lower part of the formation in the western part of the quadrangle, and was mapped across much of the Sand Arroyo and Bug Creek Quadrangles to the south (Rigby and Rigby, 1990).

Some weathered slopes of mudstones and claystones are littered with small crystals of selenite, apparently related to break down of sulfides during the weathering process.

Gray metallic marcasite concretions are common throughout the Lower Hell Creek Formation, but are particularly evident in the unconsolidated sandstones that may make up the lower units of the formation in sections east of the Barbeque Quarry dinosaur locality and in southernmost exposures in the south-central part of the quadrangle.

An environmental interpretation of the sequence in the quadrangle is like that described for equivalent beds in the Sand Arroyo and Bug Creek Quadrangles to the south (Rigby and Rigby, 1990, p. 101). "The organic shale, coal, and siltstone-mudstone of the formation represent flood plain deposits, in contrast to the sandstones that appear to be deposits of meandering and braided channels and splay systems." These rocks accumulated onshore from the margin of the regressive Late Cretaceous seaway.

Fossils and Age.—The Hell Creek Formation, as mapped in the quadrangle, includes youngest Cretaceous and basalmost Paleocene rocks. The Hell Creek Formation is of Late Maastrichtian age (Sloan and others 1986), but also include a few meters of basal Paleocene rocks above the iridium layer and below the formational or upper Z-Coal. The formation is the principal dinosaur-bearing unit in eastern Montana.

Thickness.—Within the Mc Rae Springs Quadrangle, the formation is approximately 62 meters thick. The dinosaur bone bed at Barbeque Quarry (Figures 10 and 11) (Roberts, 1998) occurs approximately 40 meters above the base and 20 meters below the top of the formation.

Tertiary System
Paleocene Series
Tullock Formation

Introduction.—Only the basal part of the Tullock Formation is preserved in the quadrangle as high caps of butte-like outliers in southeastern sections of the quadrangle (Figure 2). Thickest preserved exposures are in the central and southeastern part of Section 35 T. 25 N., R. 43 E., in the southeastern corner of the mapped area, where approximately 15 meters of the lower Tullock Nelson Ranch Member (Rigby and Rigby, 1990) is exposed. Three small outliers occur north of the headwaters of Beaver Creek, in Sections 26 and 27 of T. 25 N., R. 43 E., and include from only a few meters, in the small outlier, to perhaps 15 meters in the larger isolated erosional remnants.

The Tullock Formation overlies the Hell Creek Formation in the quadrangle and areas to the south, where it is more extensively exposed in the Bug Creek and Sand Arroyo Quadrangles. The Tullock Formation is the basal Tertiary unit of that sequence and was named by Rogers and Lee (1923, p. 29) for the interbedded yellowish sandstones and shales, with minor lenticular coal beds, that occur in what was then termed the upper part of the Lance Formation in the Tullock Creek coal field, in Treasure County, Montana. The beds have a complex history of stratigraphic nomenclature, summarized by Frye (1969) and Rigby and Rigby (1990.)

Collier and Knechtel (1939, p. 11) discussed the Tullock beds as a member of the Lance Formation and noted the questionable Eocene age for the rocks, but in a footnote they reported that the underlying Hell Creek beds had been reassigned to the Cretaceous and the Tullock beds to the Cretaceous or Eocene by the U. S. Geological Survey. Brown (1938) placed the Cretaceous-Tertiary boundary where it is currently mapped, between the Hell Creek and Fort Union or Tullock beds, for the first time and discussed reasons for placing the boundary there. As late as 1959, however, confusion still persisted because Denson and others (1959) concluded there were no distinct lithologic reasons for differentiating what had been called upper and lower Hell Creek beds, in spite of Brown (1952) pointing out that the top of the lower Hell Creek beds marked the uppermost limit of common *Triceratops*. Stanton (1909, p. 286) correctly concluded that earlier collected floras were mixed and that the dinosaur-bearing beds ought to be separated from the overlying Tullock rocks. Dorf (1942, p. 95–97) correctly concluded that rocks now commonly included in the Tullock Formation, in northern Wyoming, contain plants of typical Paleocene floras and are not of uppermost Cretaceous age.

Rigby and Rigby (1990) mapped the boundary between the Tertiary Tullock formation and underlying Hell Creek formation at the base of the upper or formational Z-Coal, although as reported by others, the pollen break and the carbonaceous clay of the iridium anomaly at the precise Cretaceous-Tertiary boundary occur one to six meters (commonly two to three meters) below that coal. The carbonaceous shale, however, that marks the iridium layer is less easily mapped and the formational contact on the geologic map in the Bug Creek and Sand Arroyo quadrangles was drawn at the base of the upper Z-Coal, as we have done here in the limited outcrops of the Tullock Formation in the southeastern part of the Mc Rae Springs Quadrangle.

Rigby and Rigby (1990) erected the Nelson Ranch Member for the lower part of the formation and the Collins Ranch Member for the upper part of the formation. Only rocks included in the Nelson Ranch Member are preserved in the Mc Rae Springs Quadrangle. Rigby and Rigby (1990, p. 104) concluded that the Tullock Formation apparently rests unconformably across the Hell Creek Formation in the Bug Creek and Sand Arroyo quadrangles, as was earlier observed by Rigby and others (1986). That unconformity is marked by development of numerous Paleocene stream channels cut down into the Cretaceous beds, and by variations in thickness of the Hell Creek Formation below. One such channel is well preserved in the central part of Section 35, T. 25 N., R. 43 E., where a channel of a north-flowing stream has been filled by light yellow-gray sandstone that cuts into the lowermost Tullock and uppermost Hell Creek beds. So little is preserved of the Tullock Formation and the contact zone in the quadrangle that little new information can be contributed to conclusions reached by earlier workers. In the southeastern part of the quadrangle, the thickest sequences preserved range from the contact zone up through the Z-Coal sequence to near the X-Coal in the middle and lower parts of the Nelson Ranch Member.

Lithology.—Interbedded, commonly cyclic-appearing, tan to light gray sandstones alternate with light yellow-gray to gray shales or mudstones, with locally interbedded siderite or ironstone concretions, and carbonaceous shale or minor coal, and characterize exposures in the southeastern part of the quadrangle.

Rigby and Rigby (1990, p. 106) described characteristic cycles within the lower Tullock Formations as ranging upward from moderately laterally persistent, though commonly channeled sandstone, through sideritic shales, to banded light gray or light yellow-gray siltstones. These grade upward into bentonitic claystones or mudstones, with only minor ironstones, although they may contain thin concretionary lenses of sandstone in the dominantly marshy or lacustrine section. These are capped by thin carbonaceous shales or low-rank bituminous coals and carbonaceous shale. Several such cycles are visible in bold badland exposures in the mapped outliers in divide areas on both sides of Bear Creek, but are probably best and most extensively exposed on north slopes in Section 26, T. 25 N., R. 43 E.

Fossils and Age.—Age of the lower Tullock Formation has been conclusively shown to be lower Paleocene, based on vertebrate and plant fossils from nearby areas (Shoemaker, 1966; Norton and Hall, 1969; Van Valen, 1978; Sloan, 1987; Rigby, 1985, 1987; Rigby and others, 1987; and Sloan and Rigby, 1986).

Cenozoic Deposits

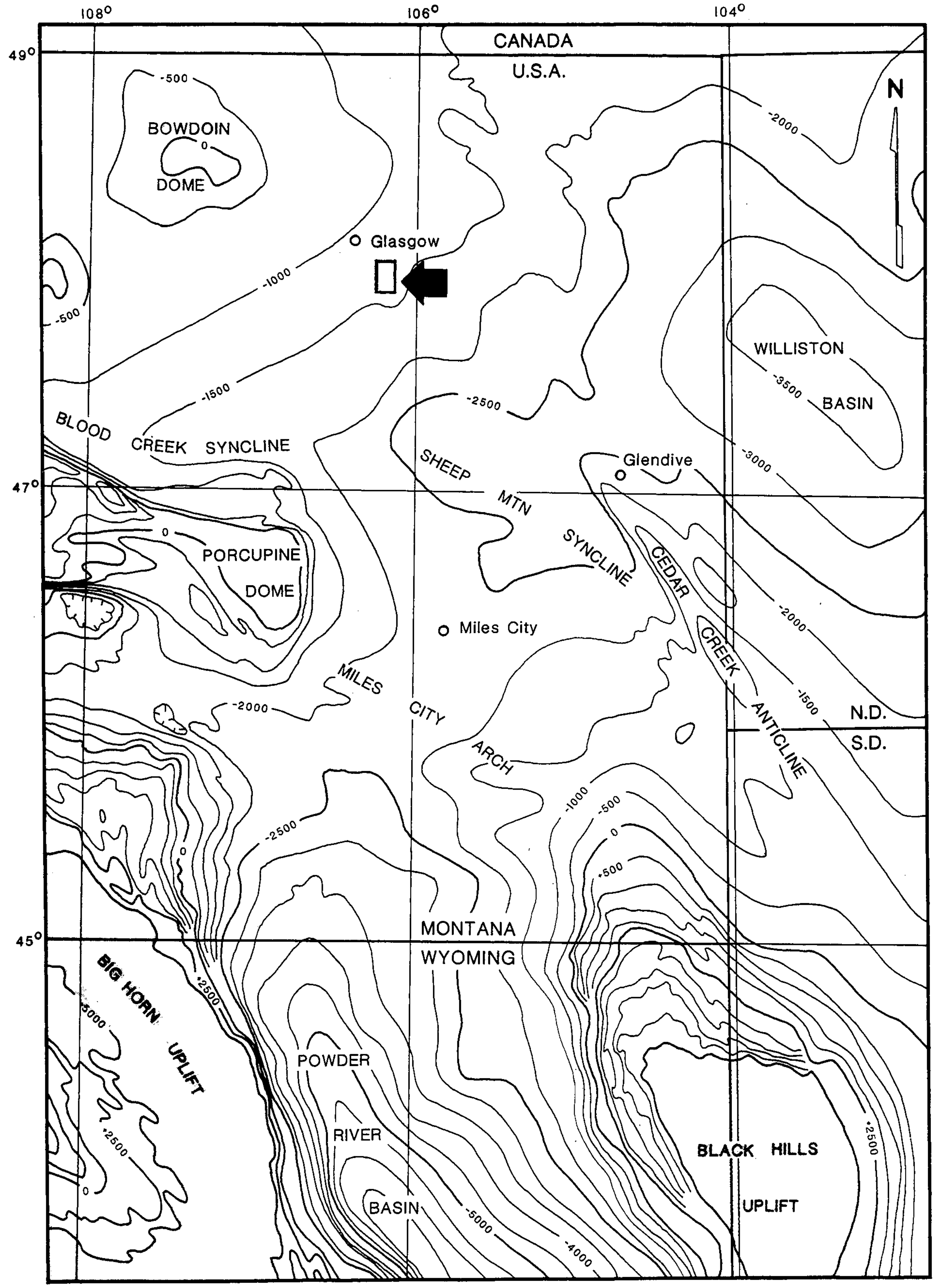
Although we were principally concerned with the Cretaceous and Tertiary bedrock exposures, we have differentiated broad areas of Quaternary alluvial fill in the flat valley bottoms of Bear Creek, in the south, and tributaries of Hungry Creek and Lost Creek, in the northeastern part of the quadrangle. Some moderate terrace development shows as abandoned benches, particularly along Cheer Creek and the West Fork of Hungry Creek in the east-central part of the quadrangle. Throughout the area, present drainages are uniformly entrenched into the fill of the flat valley bottoms.

Collier and Knechtel (1939, Plate 8) showed Iowan (?) or Illinoisan (?) ground moraine covering all of the quadrangle, and extending for several miles to the south in McCone County and Garfield County. They mapped the southern limits of Wisconsin ground moraine in Valley County and Roosevelt County about thirty miles north of the Missouri River and the Mc Rae Springs Quadrangle.

Uplands in the quadrangle are commonly veneered by unconsolidated pebble and cobble gravels that contain a mixture of red and green quartzite, black chert, and fragments of igneous and metamorphic rocks. Associated with these are large blocks and cobbles of exotic igneous and metamorphic rocks. These are commonly only a few centimeters in diameter, but fragments 50 cm to 1 m in diameter are moderately common and appear as light exotic elements across the landscape. Locally large blocks, a meter or more in diameter, also occur as light gray, isolated exotic elements scattered over the hills.

Many of the small pebbles are reminiscent of lithologies common in the Belt Terrain in mountains to the west. Whether all of the upland gravels are associated with a ground moraine source, or represent terrace gravels abandoned by the down-cutting Missouri River, remains a project for analysis. We have not attempted to differentiate these Pleistocene deposits throughout the quadrangle.

Figure 12. Regional structure contour map showing the Mc Rae Springs quadrangle (arrow) situated on the southeast homoclinal flank of Bowdoin Dome and the western part of the Williston Basin (modified from Rigby and Rigby, 1990).


108°
106°
104°
49°
47°
45°
CANADA
U.S.A.
N
BOWDOIN
DOME
-500
0
Glasgow
-1000
-1500
-2000
-2500
WILLISTON
-3500
BASIN
-3000
BLOOD CREEK SYNCLINE
SHEEP MTN SYNCLINE
Glendive
CEDAR CREEK ANTICLINE
PORCUPINE
DOME
Miles City
MILES CITY ARCH
N.D.
S.D.
-1000
-500
0
+500
MONTANA
WYOMING
BIG HORN UPLIFT
+2500
-5000
POWDER
RIVER
BASIN
-4000
BLACK HILLS
UPLIFT

STRUCTURE

Bedrock units in the quadrangle are essentially flat lying, with a simple homoclinal dip towards the southeast, as evidenced by the contact of the Fox Hills Sandstone and overlying Hell Creek Formation occurring at an elevation of approximately 2610 feet in the west-central part of the quadrangle, near Coal Hill, and the same contact occurring at an elevation of approximately 2430 along the lower part of Widow Coulee, in the southeastern part of the quadrangle. This amounts to a drop of approximately 180 feet in 6 miles, or at a rate of 30 feet per mile, which amounts to a general regional dip of approximately 0.5 degrees.

A somewhat lesser dip of approximately 17 feet per mile is suggested by the contact of the Fox Hills Sandstone on the Bearpaw Shale, which is at an elevation of 2490 feet in the northwestern part of the quadrangle, but slopes down southeastward to an elevation of approximately 2370 feet, in exposures east of Cheer Creek in the east-central part of the map.

No major faults or even marked regional folds are evident in the virtually homoclinal formational sheets in the quadrangle. The quadrangle is located on the southeast flank of Bowdoin Dome, in the simple homoclinal structure shown there on the generalized structural contour map of the United States (Figure 12, modified from Rigby and Rigby 1990).

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