

**THE SLOPE (PALEOCENE) AND BULLION CREEK (PALEOCENE)
FORMATIONS OF NORTH DAKOTA**

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REPORT OF INVESTIGATION NO. 59
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E. A. Noble, State Geologist
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ABSTRACT

Stratigraphic problems in correlating the Ludlow and Tongue River Formations between North Dakota and adjacent areas are best resolved by a revision of the nomenclature and the introduction of two new formation names, the Slope Formation and the Bullion Creek Formation. The newly defined Slope Formation (Paleocene) consists of strata that have been considered to be the upper part of the Ludlow Formation or part of the Tongue River Formation. The newly defined Bullion Creek Formation (Paleocene) consists of strata that have been considered to be equivalent to either the entire Tongue River Formation or to the lower, middle, or upper part of the Tongue River Formation.

INTRODUCTION

Over the years, many attempts have been made to correlate the complex sequence of continental deposits that make up the Fort Union Group over areas in which surface exposures are scarce and testhole data were lacking. Most of the Upper Cretaceous and Tertiary formations in western North Dakota were introduced without designating specific type sections, and these poorly defined formation terms have commonly been extended great distances to other areas from their original localities without the benefit of detailed correlation or specific criteria for recognition of formational boundaries. This has led to placing contacts at different horizons in different areas.

With the completion of detailed field studies of Fort Union Group strata in southwestern North Dakota and nearby areas recently, numerous stratigraphic inconsistencies have become apparent. Several stratigraphic problems have arisen in correlating the Ludlow and Tongue River Formations between North Dakota and adjacent South Dakota and Montana. These problems can be best resolved by revising the nomenclature and by introducing two new formation names, the Slope Formation and the Bullion Creek Formation (fig. 1).

The Slope Formation is a drab-colored, lignite-bearing sequence that overlies either the Cannonball Formation or the Ludlow Formation. It is separated from the similar-looking, underlying Ludlow Formation strata by the T Cross bed, which occurs at the top of the Ludlow. The sequence that is included in the Slope Formation has, in the past, been considered to be equivalent to the upper part of the Ludlow Formation or to part of the Tongue River Formation.

The Bullion Creek Formation consists of a bright-colored, lignite-bearing sequence that occurs beneath the drab-colored Sentinel Butte Formation and above the white marker zone at the top of the Slope Formation. The sequence has been considered to be equivalent to either the entire Tongue River Formation or, variously, to the lower, middle, or upper parts of the Tongue River Formation.

THE LUDLOW PROBLEM

The Ludlow was introduced by Lloyd and Hares (1915) as a lignitic member between the "Cannonball and Hell Creek members of the Lance Formation" in northwestern South Dakota and southwestern North Dakota. Hares states that the type locality is near the Ludlow post office (1928, p. 24) and later states (p. 47) that the Giannonatti bed of northwestern South Dakota corresponds to the T Cross bed of southwestern North Dakota. Hares restricted the term "Ludlow member" to beds below the "Cannonball member" in South Dakota; he mapped the top of the Ludlow at a higher horizon in western North Dakota. He considered a sandstone bed to be the base of his "Tongue River member of the Fort Union Formation" in the Marmarth area, considering it to be similar to a sandstone bed overlying the "Cannonball member" in exposures along the Cannonball River.

Moore (1976, p. 35), in detailed studies of these strata in Slope County (fig. 2), recognized a "white siliceous bed," which he described as aphanitic to fine-grained quartz, a few centimetres to a few metres thick, white on fresh fractures,

White River Group		Oligocene	Tertiary
Golden Valley Formation		Eocene	
Fort Union Group	Sentinel Butte Fm.	Paleocene	
	Bullion Creek Fm.		
	Slope Fm.		
	Cannonball Fm.		
	Ludlow Fm.		
Hell Creek Formation		Cretaceous	

Figure 1. Stratigraphic column incorporating revisions of the Fort Union Group as proposed in this paper.

but buff or yellowish on weathered surfaces. The siliceous bed is commonly overlain by lignite or lignitic shale, and it overlies a variety of sediment types, which are bleached white. The bleached zone ranges from a few centimetres to as much as ten metres thick. Moore found this white marker zone to be a useful marker for the top of the Ludlow in Slope County, although he noted that Hares (p. 48) considered this "quartzite" marker to be just below the H bed, about 60 feet above the base of his Tongue River in the Marmarth area. Carlson, in agreement with Moore, found the white marker zone to be a useful marker in mapping the contact between the Ludlow and Tongue River Formations in Bowman, Adams, Grant, and Morton Counties.

The white marker zone is relatively persistent, but it is not unique within the lignite-bearing zone. Moore noted small surface exposures of a similar material well below the white marker zone along Horse

Creek in Slope County. Also, the lower member of the Golden Valley Formation, where the whitish silty clay is capped by a siliceous bed such as at Pretty Rock Butte (T131N, R89W), is similar in appearance, but it is separated from the white marker zone by a stratigraphic interval sufficiently thick to eliminate the possibility of confusion. Siliceous zones bearing petrified wood also occur at various horizons within the lignite-bearing strata. These are not associated with white bleached zones, so they are not likely to be confused with the white marker zone. White siliceous beds about 50 to 80 feet above typical Cannonball Formation sediment in areas of poor bedrock exposures in Adams, Grant, and Morton Counties (fig. 2) are considered to be equivalent to the white marker zone.

Moore divided the Ludlow into lower and upper units, with the T Cross bed as the base of the upper unit. He noted brackish-water units in Slope County. A 3- to 6-foot-thick bed of clay directly overlies

EXPLANATION

- ⊙ TYPE SECTION BULLION CREEK FORMATION
- TYPE SECTION SLOPE FORMATION
- x EXPOSURES OF WHITE MARKER ZONE
- ⊙ TYPE AREA OF LUDLOW FORMATION



Figure 2. Map of southwest North Dakota and Harding County, South Dakota showing locations of type sections for the Bullion Creek and Slope Formations and type area for the Ludlow Formation. Exposures of the white marker zone are designated by crosses.

the T Cross bed and an "oyster clay and lignite" bed occurs approximately 150 feet above the T Cross bed. The white marker zone is well above the brackish beds in this area. In South Dakota, the Ludlow has been limited to the nonmarine strata between the Hell Creek and Cannonball strata. In the absence of Cannonball strata, a sandstone bed near the horizon of the Giannonatti bed has been considered to be the base of the Tongue River. The white marker zone is present in the North Cave Hills of South Dakota (fig. 3) where it is present well above the "basal Tongue River sand" and also above "lignite F" of Pippingos and others (1965, p. A6).

Some of the various criteria for placing the Ludlow-Tongue River contact are shown as alternatives in a series of diagrams (fig. 4). Alternatives A to C represent current or past practice while alternatives D to G represent options considered in this paper. Alternative A shows the Tongue River on Ludlow in the western part of the area and on Cannonball in the eastern part of the area. This alternative illustrates common practice in the past. A' shows the actual position of the white marker zone and the stratigraphic relationship of the Cannonball Formation to the nonmarine strata; the base of the Tongue River has therefore been placed at different stratigraphic horizons in the western and eastern areas as shown in A". Alternative B corrects this nomenclature problem by extending the term Ludlow above the Cannonball and subdividing the Ludlow into upper and lower members where the Cannonball is present. Alternative C illustrates current practice in South Dakota, where Ludlow is used either for the nonmarine strata between the Hell Creek and Cannonball Formations or for strata between the Hell Creek and either the Giannonatti lignite bed (Stevenson, 1956) or the "Carbonate No. 2 lignite bed" (Pippingos and others, 1965) where the Cannonball is absent.

In North Dakota, we now recognize mappable nonmarine strata both above and below the Cannonball Formation in the interval between the Hell Creek Formation and the white marker zone. In the western area the T Cross bed is overlain by

brackish-water clay; this has been used to divide the Ludlow into upper and lower members. Alternative D represents current practice in western North Dakota, except that Ludlow is restricted to the western area; and new names are introduced for the nonmarine strata above and below the Cannonball Formation to the east. Alternative E would restrict Ludlow to the strata between the Hell Creek and Cannonball Formations. It would introduce a new name for the strata between the Cannonball Formation and the white marker zone in the eastern area and a new name for the strata between the Hell Creek and the white marker zone in the western area. Alternative F would extend Montana names into North Dakota for the strata between the Hell Creek and Tongue River Formations. Alternative G continues the use of Ludlow as it has been used in the eastern area and extends it westward; a new name is required for the strata between the T Cross bed and the white marker zone, and this new name is extended eastward between the Cannonball Formation and the white marker zone.

Alternative A is inappropriate because recent mapping (Carlson, Clayton, unpublished) has shown that the bright/drab contact and the white marker zone can be traced eastward, well above the top of the Cannonball Formation; it does not accurately depict the actual stratigraphic relationship. Alternatives B and D seem inappropriate because the Ludlow Formation in South Dakota is typically restricted to beds below the Cannonball Formation or below beds considered to be equivalent to the T Cross bed in North Dakota (Lloyd and Hares, 1915; Stevenson, 1956; Pippingos, Chisholm, and Kepferle, 1965). Alternative C follows South Dakota usage, but it is inappropriate because (1) it places the base of the Tongue River Formation much lower than it has usually been placed in southwestern North Dakota, and (2) it includes drab beds in the otherwise bright Tongue River.

Alternative E has the advantage of restricting the long-established Ludlow to the strata between the Hell Creek and Cannonball Formations, but it has the

SECTION NEAR
LUDLOW, SOUTH DAKOTA
(Modified from Pipiringos
and others, 1965, A6)

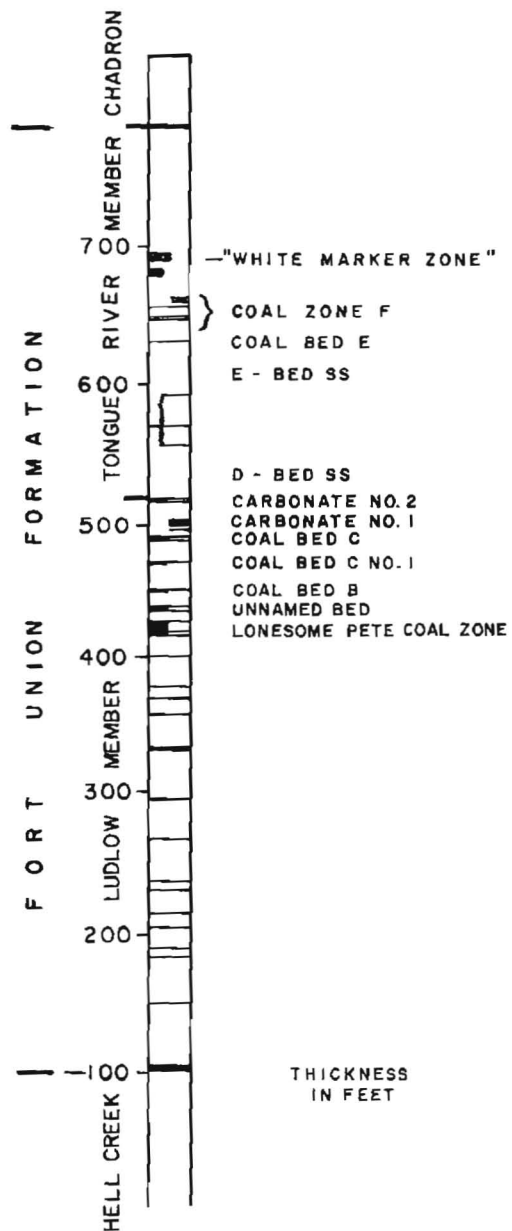


Figure 3. Generalized stratigraphic section from the North Cave Hills near Ludlow, South Dakota.

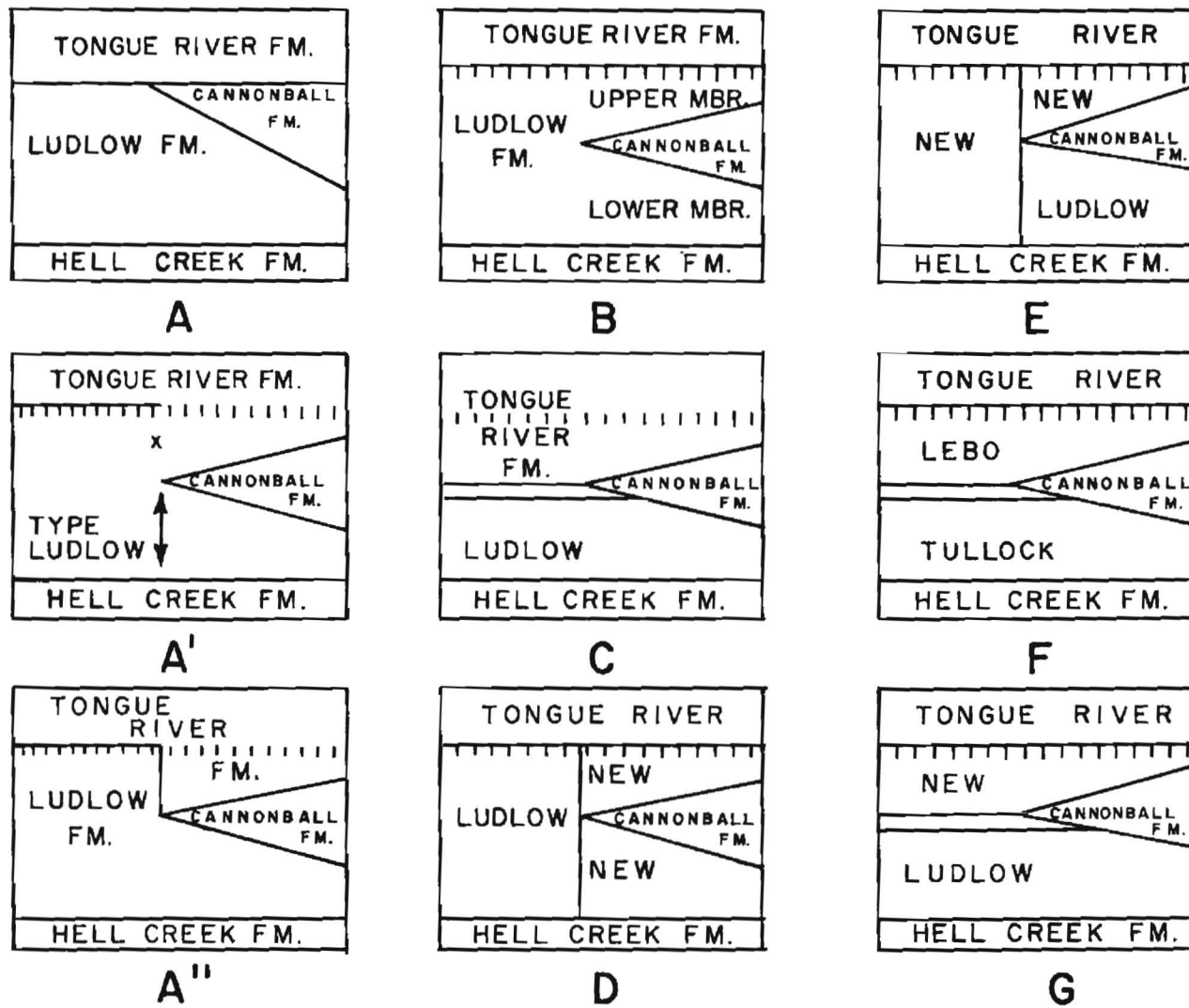


Figure 4. Diagrammatic cross sections showing alternative solutions to the Ludlow problem. Alternatives A through C represent past or current practice; D through G are options considered in this paper.

disadvantage of requiring two new names.

Alternative F has the disadvantage of dropping the term Ludlow, and it extends the Montana terms long distances from their type areas. The Lebo in Montana is generally described as a drab shale unit between the light-colored Tullock and Tongue River strata. The Lebo contains very little lignite. In North Dakota, the interval between the Hell Creek and the T Cross bed is generally drab, the interval between the T Cross bed and the white marker zone is mostly drab with some bright beds, and the strata above the white marker zone is generally bright.

We prefer to use Alternative G to solve the Ludlow problem. It restricts Ludlow to strata between the Hell Creek and Cannonball in the eastern area and to the interval between the Hell Creek and T Cross bed in the western area. This usage is consistent with usage in the Ludlow type area in northwestern South Dakota. Alternative G requires the introduction of a new name for the strata between the T Cross bed and the white marker zone. This new unit is here named the Slope Formation.

SLOPE FORMATION (NEW NAME)

Source of name.—Slope County, North Dakota, where the formation is best exposed.

Type area and section.—The type area is T105N, R135W, in Slope County. The type section (fig. 5) is in the south-facing exposure in the northwest corner of section 15 and the southwest corner of sec 10, T105N, R135W.

Description.—The Slope Formation, like the other nonmarine Paleocene formations of the Williston basin, consists of alternating beds of clay, silt, sand, and lignite (Moore, 1976). Most of the sediment is unlithified or only moderately lithified. The clay and silt is unbedded or thinly laminated but nonfissile. The sand has plane bedding or large-scale or small-scale crossbedding. Less than a tenth of the unit is lignite, which typically occurs in beds less than 4 metres thick. Although light yellowish beds are present and the

sedimentary rock over burned lignite beds is brick red, the unit is predominantly drab, brownish gray.

Contacts.—The Slope Formation rests on the Cannonball Formation in central North Dakota and on the Ludlow Formation in western North Dakota where the Cannonball is generally absent. In its type area in South Dakota, the top of the Ludlow Formation is considered to be approximately at the top of "Carbonate No. 2 coal bed" (Pipiringos, Chisholm, and Kepferle, 1965) or near the top of the Giannonatti bed (Stevenson, 1956). The Giannonatti bed has been considered equivalent to the T Cross bed in North Dakota (Hares, 1928, p. 47). The top of the T Cross bed is here considered to be at the contact between the Ludlow Formation and the Slope Formation in areas where the Cannonball Formation is absent. Moore (1976, p. 23) placed the contact between his upper and lower Ludlow slightly lower at the base of the T Cross bed so that all of the thick lignite beds would be in his upper unit, which essentially corresponds to the Slope Formation.

The Slope Formation is apparently unconformably overlain by the Bullion Creek Formation (Moore, 1976). The top of the Slope Formation is marked by a widespread, white bleached zone, which is commonly associated with a siliceous bed (the white marker zone of the previous discussion).

Thickness and regional extent.—The Slope Formation is about 90 metres thick in its type area. It is exposed along the western margin of the Williston basin into eastern Montana, apparently as far south as the Cedar Creek anticline. Outcrops are poor around the southeastern margin of the basin, but the formation is known to extend northward into Morton County, where it has thinned to about 20 metres. The maximum northeastward extent of the Slope Formation is unknown, but the formation probably becomes unmappable near Washburn in McLean County. The lower part of the Slope Formation is present in northwestern South Dakota, where it is included in the Tongue River Formation.

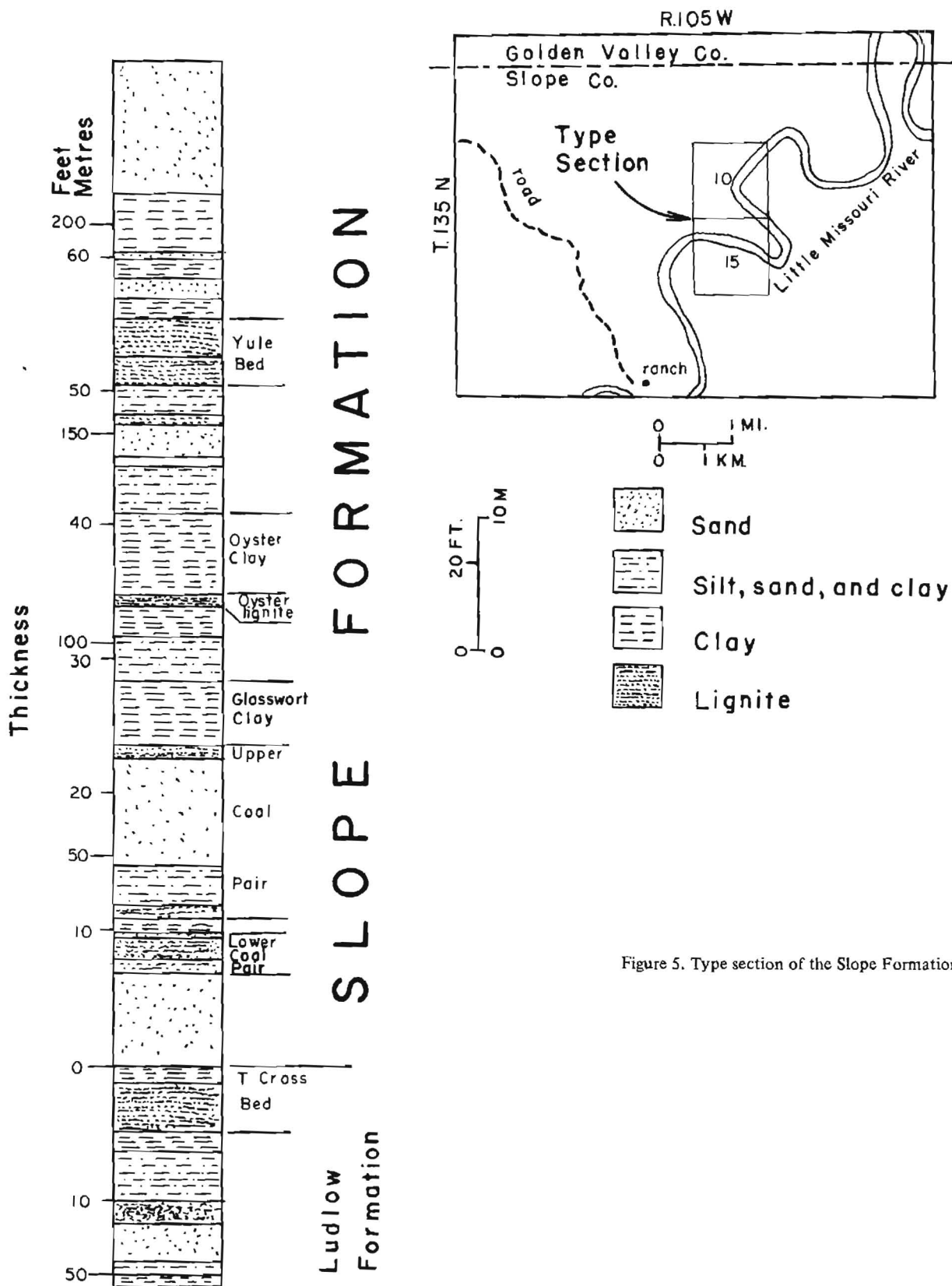


Figure 5. Type section of the Slope Formation.

Differentiation.—The Slope Formation is distinguished from the overlying Bullion Creek Formation by its color; in outcrop the Slope Formation is largely drab, brownish gray, while the Bullion Creek is largely light yellow. In areas of poor outcrop, the contact can sometimes be identified (Moore, 1976, p. 35-36) by the presence of the white marker zone at the top of the Slope Formation. This bed could probably be confused only with the lower member of the Golden Valley Formation.

THE TONGUE RIVER PROBLEM

The term Tongue River was introduced by Taff (1909, p. 129) to refer to a group of lignite beds in the Sheridan coal field, Wyoming. In that area these beds were reported as about 850 feet thick. In the adjacent Moorhead coal field, Montana, Bryson and Bass (1973) include 1,400 to 1,600 feet of lignite-bearing strata in the "Tongue River member" of the "Fort Union Formation." In both areas the Tongue River is overlain by the Wasatch Formation of Eocene age.

The Slope Formation and the Sentinel Butte Formation are both drab-colored units that are separated from each other by a bright-colored unit. Leonard (1908) and Leonard and Smith (1909) were perhaps the first to recognize this bright-colored unit in North Dakota; they referred to this unit as "middle Fort Union." Thom and Dobbin (1924) correlated it with the "Tongue River member" of the "Fort Union Formation" in the Powder River basin for the following reasons: both units are about the same age, both have a similar lithology, both are generally bright colored, both are underlain by drab-colored units, and both were thought to be overlain by Eocene beds. "Tongue River" was the generally accepted name for the bright-colored unit in North Dakota until Brown (1948) showed that the Sentinel Butte Formation is Paleocene, not Eocene. The Sentinel Butte was then reduced in rank, and both it and the unnamed, bright-colored unit were considered to be members of the Tongue River Formation

(Hansen, 1956). Later, Royse (1967) argued that the Sentinel Butte is mappable and should be re-elevated to formation rank. He recommended that the "Tongue River Formation" in North Dakota be restricted (again) to the bright-colored beds under the Sentinel Butte Formation. This recommendation was followed by later North Dakota geologists (Carlson, 1969; Jacob, 1976).

The base of the bright-colored unit (Royse's "Tongue River") was long ago placed at the base of a sandstone bed in southwestern North Dakota (Hares, 1928, p. 24). Most geologists mapping in the area where Cannonball is present have also recognized a sandstone bed at the base of the bright-colored beds. It now appears that this sandstone bed is below the previously mentioned white marker zone and is either a shoreline facies of the receding Cannonball sea or a fluvial deposit of the Slope Formation.

In the North Cave Hills of South Dakota the white marker zone is present above "coal zone F" (Pipiringos and others, 1965, p. A6). Vertebrate remains have been collected from "D" bed and "E" bed sandstones indicating a brackish or marine environment (probably the Cannonball Formation). This suggests that the interval between the white marker zone and "Carbonate No. 2 coal bed," which is included in the Tongue River Formation in South Dakota (fig. 3), is probably equivalent to the newly defined Slope Formation of North Dakota.

In Montana, Baker (1929), Oliver (1957), and Bryson and Bass (1973) have noted that the upper part of the Tongue River has some beds that are as drab colored as the overlying Eocene beds; perhaps the Sentinel Butte Formation is equivalent to the upper part of type Tongue River. In the measured section of Bryson and Bass (1973, p. 13) petrified wood is noted through about the upper 475 feet of section down to just below the Dietz lignite. Below this horizon petrified wood was not noted. In North Dakota, petrified wood zones are common in the Sentinel Butte strata, but they are rarely found in the bright-colored strata below the Sentinel Butte.

Thus, the interval between the white marker zone and the color change along the Little Missouri River appears to be only a part of the strata mapped as Tongue River Formation in South Dakota or Tongue River member of the Fort Union Formation in Montana. To avoid the confusion of using different criteria for defining the Tongue River in different areas, the bright-colored beds between the white marker zone and the drab Sentinel Butte Formation are here named the Bullion Creek Formation.

BULLION CREEK FORMATION (NEW NAME)

Source of name.—Bullion Creek, 5 kilometres north of the type section.

Type area and section.—The type area is within a radius of 15 kilometres of Bullion Butte. The type section (fig. 6) is the Red Hills section of Crawford (1967) in the southwest quarter of section 27, the southeast quarter of section 28, the northeast quarter of section 33, and the northwest quarter of section 34, T137N, R103W, Golden Valley County, North Dakota (Crawford called this unit the "lower member of the Tongue River Formation").

Description.—The Bullion Creek Formation consists of alternating beds of clay, silt, sand, and lignite. The clay and silt beds are unbedded to sharply bedded but are generally nonfissile; laminations a millimetre or less in thickness are common. About a tenth of the formation is sand; the bottom part is especially sandy. The sand typically has both small-scale and large-scale, commonly trough-shaped, crossbedding. A small proportion of the sand is cemented, forming ledges or butte caprock. Less than a tenth of the formation is lignite. Lignite beds are typically about a metre thick, but beds at least 4 metres thick are present in many areas. Where lignite beds have burned, the overlying sediment has been baked, producing bright red colors. Most of the Bullion Creek Formation has a light yellowish hue in outcrop.

Contacts.—The Bullion Creek

Formation is conformably overlain by the Sentinel Butte Formation. The Bullion Creek rests apparently unconformably on the white marker zone at the top of the Slope Formation.

Regional extent.—The Bullion Creek Formation occurs throughout western North Dakota. A few small patches occur in northwestern South Dakota, and equivalent sediment occurs in southeastern Saskatchewan where it is included in the Ravenscrag Formation. The Bullion Creek Formation can be recognized westward into Montana at least as far as the Cedar Creek anticline. Southwest of the Cedar Creek anticline a facies change may occur. Both the Bullion Creek and Sentinel Butte Formations are probably equivalent to at least part of the Tongue River member of the Fort Union Formation of the Powder River basin.

Thickness.—In the type area, the Bullion Creek Formation is nearly 100 metres thick. It is about 200 metres thick near the middle of the Williston basin and thins to about 50 metres around the south and east edges of the basin.

Differentiation.—The Bullion Creek Formation is distinguished from the overlying Sentinel Butte Formation by color; in outcrop the Bullion Creek is generally light yellow, whereas the Sentinel Butte is generally drab, grayish brown. Two beds (the "Upper Yellow Bed" and the "Lower Yellow Bed") within the Sentinel Butte Formation are similar in color to the Bullion Creek Formation, and a few beds within the Bullion Creek Formation are nearly as dark as the Sentinel Butte Formation; even so, color is the most distinctive characteristic for differentiation of the two formations. In areas of poor outcrop, and in the subsurface, where the sediment is unoxidized and the color distinction is less obvious (the Sentinel Butte is olive or bluish gray, whereas the Bullion Creek is brownish gray in fresh, moist, unoxidized samples), other lithologic characteristics may be useful; they have been described in detail by Royse (1967 and 1970) and Jacob (1973 and 1975).

The Bullion Creek Formation is distinguished from the underlying Slope

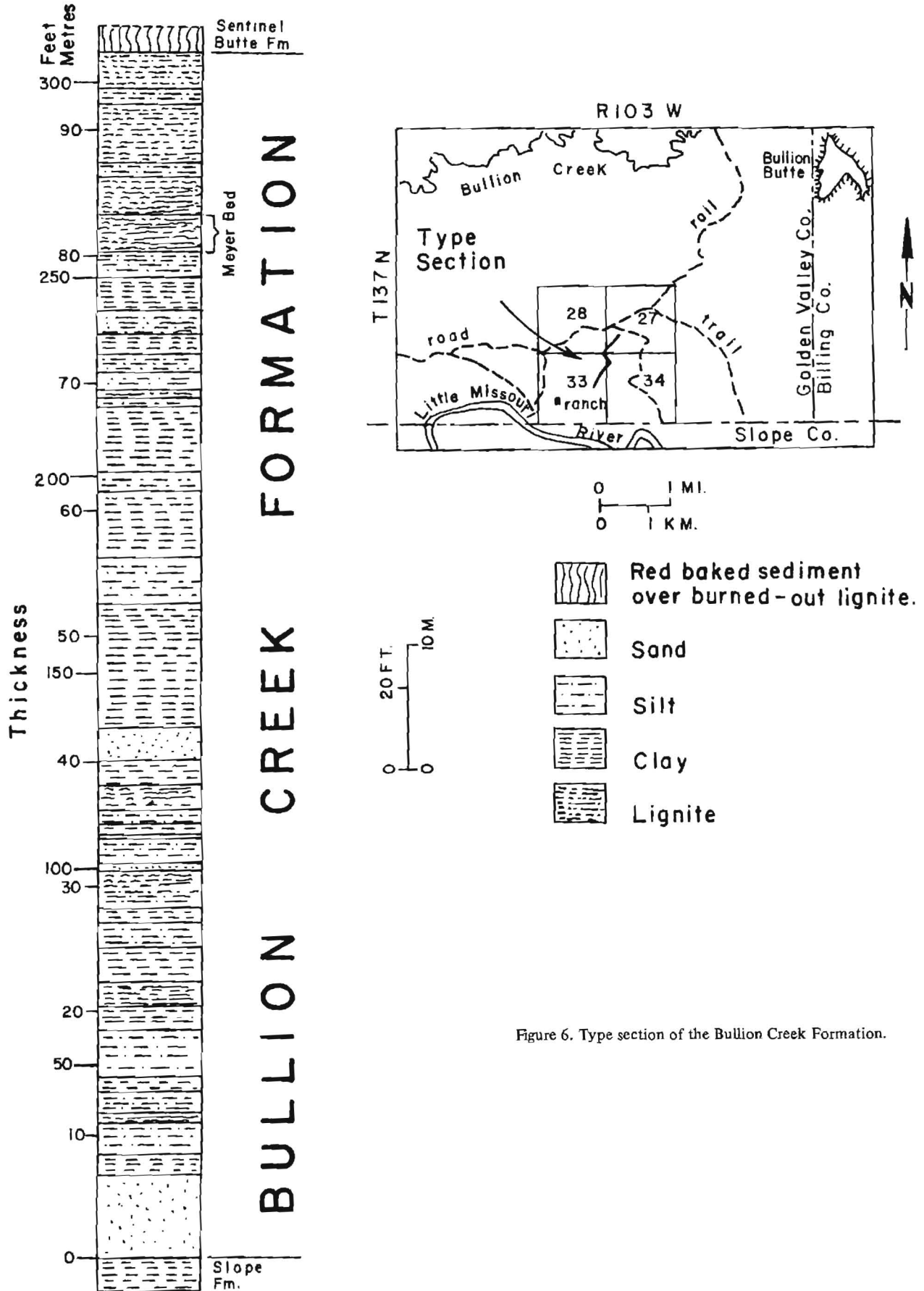


Figure 6. Type section of the Bullion Creek Formation.

Formation by color (the Slope is generally darker) and by the presence of a white marker zone below the unconformity between the two units.

Age and origin.—The Bullion Creek

Formation consists of Paleocene (Brown, 1962) fluvial-plain deposits, including overbank, flood basin, and point-bar sediment (Jacob, 1976).

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