GEOLOGY

of

ADAMS AND BOWMAN COUNTIES, NORTH DAKOTA

by
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INTRODUCTION

Purpose of Study

This report describes the general geology of Adams and Bowman Counties, an area of about 2 160 square miles, located in southwestern North Dakota (fig. 1). It is one of a series of reports prepared by the North Dakota Geological Survey in cooperation with the North Dakota State Water Commission and the United States Geological Survey in the county groundwater study series.

The primary purposes of these studies are: (1) to provide a geologic map of the area; (2) to locate and define aquifers; (3) to determine the location and extent of other mineral resources in these counties; and (4) to interpret the geologic history of the area.

Methods of Study

North Dakota Highway Department road maps, scale 1:63 360, were used as base maps. The general practice was to traverse all roads and trails by vehicle and to traverse on foot to otherwise inaccessible areas of interest. Fieldwork was limited to one field season with some subsequent spot field checks. The exposures were examined with particular attention to formation contacts so as to provide a basis for extending contacts across areas of poor exposure.

Generally in the area of Ranges 105, 106, and 107 West the exposures are excellent, so the formation contacts and thicknesses could be determined with a reasonable degree of accuracy. East of Range 104 West the area has many good exposures, particularly near the major drainages, but individual exposures or roadcuts expose only small portions of the stratigraphic units at any one locality, so it is difficult to determine formation thicknesses. Likewise, in these areas of poor exposures, inferred contacts are somewhat doubtful.

Topographic maps of the 7.5-minute series were available during fieldwork for some areas and subsequently became available for most areas. Stereo pair photo coverage, scale 1:20 000, were available for the entire area. These aids were used in plotting the contacts on the final copy.

Subsurface information was obtained from the test-hole drilling program of the North Dakota State Water Commission and the Water Resources Division of the Geological Survey and a drilling program of the North Dakota Geological Survey and the Conservation Branch of the U.S. Geological Survey. This was supplemented by oil exploration data from the files of the North Dakota Geological Survey and a few auger holes by the North Dakota Geological Survey.

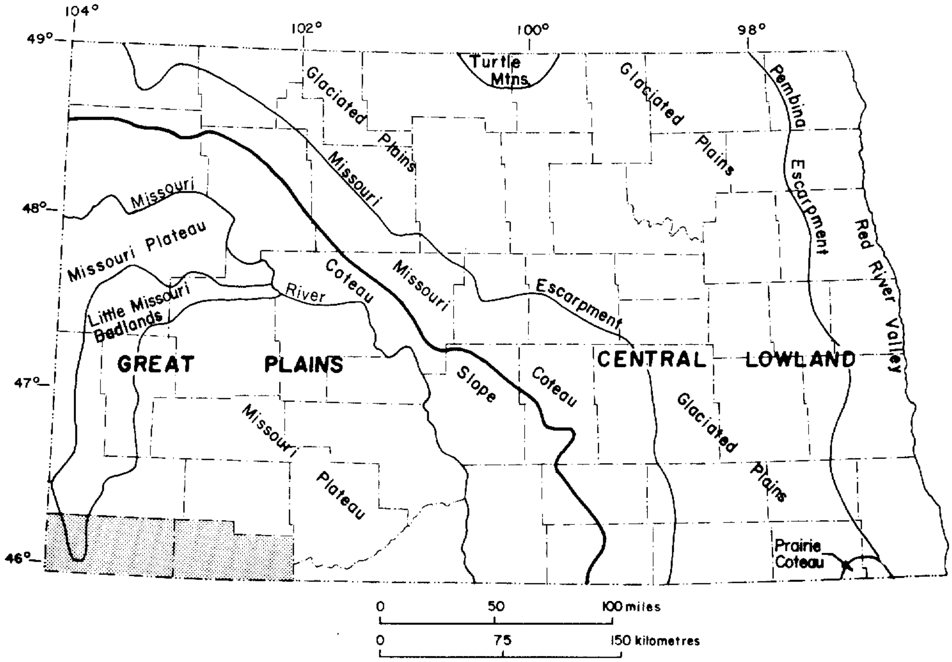

Figure 1. Location map showing area of study and physiographic divisions of North Dakota.

Previous Work

Lignite beds attracted early interest in this area and studies were conducted by both the state and federal surveys. General discussions with particular attention to specific beds or areas include those of Wilder (1902) and Leonard (1908, 1911, 1925). Lloyd (1914) provided descriptions of eastern Adams County on a township-by-township basis with special reference to the lignite beds. Hares (1928) provided a geologic map of western Bowman County, a township-by-township description of that area, and an estimate of the lignite resources of that area. Brant (1953) used available reports and summarized data on the lignite resources of these counties estimating resources of about 1.8 billion tons for Adams County and about 7 billion tons for Bowman County. Pollard and others (1972) estimated strippable reserves of about 1.37 billion tons for the Bowman and Gascoyne areas.

Uranium studies in this area include those of Denson and others (1955; 1959), Bergstrom (1956), and Zeller and Schopf (1959).

The age and terminology to be applied to the Late Cretaceous and Early Tertiary nonmarine strata overlying the

Fox Hills Formation of this area has been a continuous problem. In the early reports, the strata below the Fort Union Formation were generally referred to as the Lance Formation (Knowlton, 1911, 1922; Stanton, 1914; Dobbin and Reeside, 1930; as well as previously cited works) and the age assigned was Cretaceous, Tertiary, or both. Thom and Dobbin (1924) presented a regional summary of the relationships of the post-Fox Hills strata. They divided the Fort Union Formation into Lebo, Tongue River, and Sentinel Butte Members and the Lance Formation into Cannonball,. Ludlow, Tullock, and Hell Creek Members. However, they were undecided as to the Cretaceous or Eocene age of these formations. Hares (1928) used the term Lance with Hell Creek, Ludlow, and Cannonball Members for the strata between the Fox Hills and Fort Union in his report retaining the Tertiary (?) age for the Lance.

Paleontological studies by Brown (1938, 1962), Dorf (1940), and Jeletsky (1962) established age relationships of these strata that are presently accepted, and they defined the Cretaceous-Tertiary boundary as the top of the Hell Creek Formation. This led to discontinuance of use of the term Lance in North Dakota and inclusion of the Ludlow and Cannonball in the Fort Union.

A detailed field study of the Hell Creek Formation was conducted by Frye (1969) who divided the formation into five members. Although his member terminology was not accepted as workable map units, his study provides useful regional concepts for the upper and lower contacts of the Hell Creek. A study of the Fox Hills Formation by Feldmann (1972) provides further information on the nature of regional stratigraphic relationships and the formation contacts.

Regional Setting

The area of study includes all of Tps129 to 131N, Rs91 to 107W, and T132N, Rs95 to 107W. This area is on the south flank of the Williston Basin, an intracratonic basin whose center is about 30 miles southeast of Williston. Sedimentary rocks of each of the geologic periods are present with the thickest accumulations in this area being in northeastern Bowman and northwestern Adams Counties. The only oil test well that penetrates the complete sedimentary section is a test hole in eastern Adams County in SW¼ sec 7, T130N, R91W where Precambrian rocks are at a depth of 9 400 feet. A test hole in sec 13, T132N, R102W bottomed in the Red River Formation at a depth of 10 628 feet, so Precambrian rocks are probably at a depth of about 11 800 feet at that locality.

The Cedar Creek Anticline is a major structure that extends northwest-southeast across southwestern Bowman County into the adjacent states. The crest of this structure is reflected by the outcrop pattern of the Pierre and Fox Hills Formations (pl.

1). Some minor structures have been noted east of the anticline, but the regional dip is generally to the north, shifting from a northeasterly to a northwesterly component from west to east across the counties.

Physiography

Physiographically this area is in the unglaciated Missouri Plateau Section of the Great Plains Province. Although this area is southwest of the limit of glaciation, drainage changes caused by glaciation are affecting part of the area. The change in base level of the Little Missouri River when it became a tributary of the ice-marginal Missouri River began the erosion cycle which is presently carving the badlands. The rest of the area is characterized by generally low relief with gentle slopes interrupted by low buttes or ridges.

The Little Missouri River flows northward, draining Ranges 105 to 107 West. In most of this area the Little Missouri cuts through rocks of the Hell Creek and Fox Hills Formations (pl. 1). In these areas a band of badlands, four to six miles in width, cut 200 to 300 feet into the uplands, parallels the river. In areas where the Pierre Formation is present the slopes are gentler and there is less local relief.

The divide between the Little Missouri and the eastward -flowing Grand River is in Range 104. The Grand River flows southeastward, draining most of the remainder of Bowman County and the southwestern part of Adams County. Cedar Creek has its headwaters in Range 101 West. It drains the northeastern part of Bowman County and, with its tributaries, the remainder of Adams County. The area drained by the Grand River and Cedar Creek is a gently rolling upland with the drainage divides and scattered buttes held up by more resistant rocks within the generally soft sediments of the Tertiary and Cretaceous formations present at the surface in these counties. Resistant rock types are sandstone, "scoria," and "pseudoquartzite."

Sand is relatively common in most of the formations exposed in this area. Cementation is variable; where it is more or less continuous, sandstone is a ridge former; where irregular, it results in a series of sandstone-capped knobs along drainage divides. An example of the latter is the divide south of Flat Creek between Haynes and Hettinger (fig. 2). Other examples are Whetstone Buttes and Wolf Butte.

"Pseudoquartzite" is a finely crystalline siliceous rock that was probably deposited as a gel in ponds which had an areal extent of a few square miles. It usually contains stem-like plant remains and is present as a dense litter of lag boulders capping ridges and adjacent slopes (fig. 3). It is present in areas surfaced by sediments ranging in age from the Cretaceous Hell

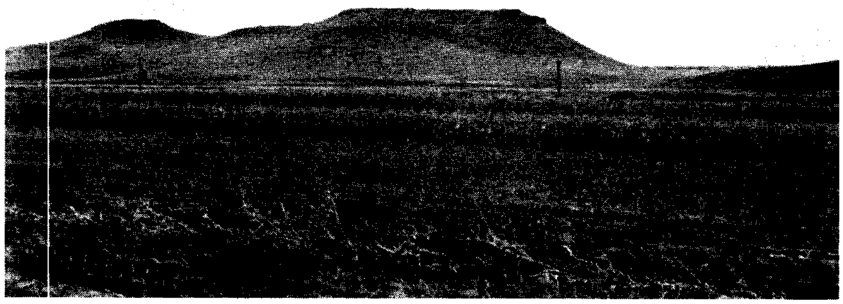

Figure 2. View of sandstone capped ridges south of U.S. Highway 12 between Haynes and Hettinger.

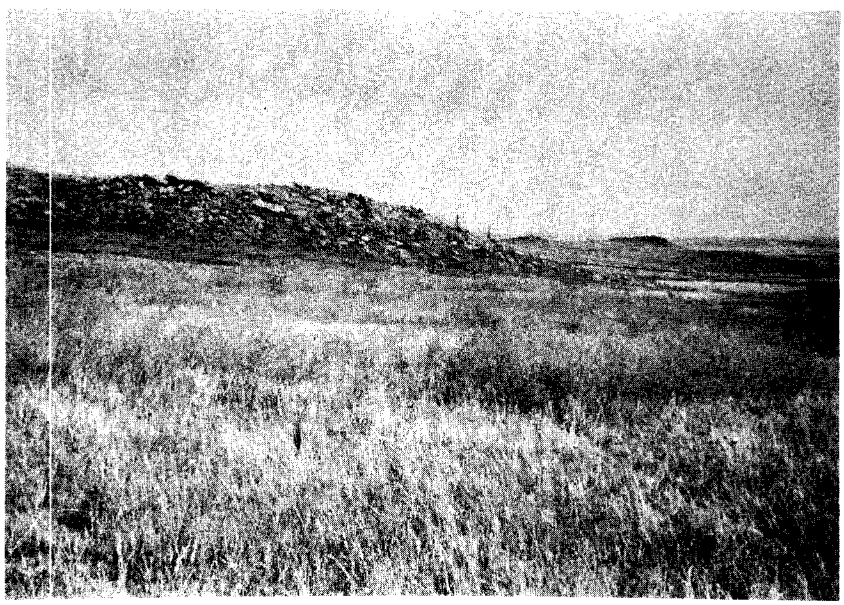

Figure 3. View of "pseudoquartzite" capped slopes in S½ of secs 27 and 28, T130N, R95W, northeast of Hettinger.

Figure 4. View of "scoria" capped buttes north of Griffin.

Creek Formation (sec 2, T129N, R105W) to the Paleocene Bullion Creek Formation (secs 7, 8, T130N, R95W).

Lignite is relatively common in each of the Tertiary formations except the Cannonball. In some areas where these beds have been exposed they have burned and baked the overlying sediment to form a clinker that is commonly called "scoria." "Scoria" is generally a reddish color and commonly caps buttes (fig. 4). Most of the low buttes in the vicinity of Rhame and Bowman are examples of this resistant type.

SUBSURFACE STRATIGRAPHY

General

The stratigraphy may be conveniently discussed by dividing the sedimentary section into sequences (fig. 5). This area was alternately an area of marine deposition and then emergence with erosion of part of the sedimentary section or occasionally nonmarine deposition. The preserved sedimentary section bounded by regional unconformities associated with the episodes of emergence has been defined as a sequence. Sequences present in this area are the Sauk, Tippecanoe, Kaskaskia,

ERA	SYSTEM	SEQUENCE	FORMATION OR GROUP		THICKNESS	DOMINANT LITHOLOGY
CENOZOIC		TEJAS		ALLUVIUM	0-30	Silt, Sand, and Gravel
				WHITE RIVER	0-80	Conglomerate, Sand, Silt, and Clay
	TERTIARY	ZUNI	FORT UNION GROUP	SENTINEL BUTTE	0-250	Silt, Clay, Sand, and Lignite
				BULLION CREEK	0-300	Silt, Clay, Sand, and Lignite
				SLOPE	0-300	Silt, Clay, Sand, and Lignite
				CANNONBALL	0-250	Mudstone and Sandstone
				LUDLOW	0-300	Silt, Clay, Sand, and Lignite
MESOZOIC	CRETACEOUS			HELL CREEK	0-500	Clay, Sandstone, and Shale
			MONTANA GROUP	FOX HILLS	0-200	Sandstone and Shale
				PIERRE	1 700-2 250	Shale
			COLORADO GROUP	NIOBRARA	200-220	Shale, Calcareous
				CARLILE	340-360	Shale
				GREENHORN	160-250	Shale, Calcareous
				BELLE FOURCHE	300-325	Shale
				MOWRY	80-160	Shale
			DAKOTA GROUP	NEWCASTLE	0-140	Sandstone
				SKULL CREEK	200-275	Shale
				FALL RIVER	150-350	Sandstone and Shale
				LAKOTA		Sandstone and Shale
	JURASSIC			MORRISON	50-60	Mudstone
				SUNDANCE	350-490	Shale and Sandstone
				PIPER	200-250	Limestone, Shale, and Anhydrite
	TRIASSIC	ABSAROKA		SPEARFISH	100-820	Siltstone and Salt
PALEOZOIC	PERMIAN			MINNEKAHTA	30-45	Limestone
				OPECHE	20-160	Shale and Siltstone
	PENNSYLVANIAN			MINNELUSA	100-270	Sandstone and Dolomite
				AMSDEN	180-320	Dolomite, Sandstone, and Shale
				TYLER	20-40	Mudstone and Sandstone
	MISSISSIPPIAN	KASKASKIA		BIG SNOWY	80-550	Shale, Sandstone, and Limestone
				MADISON	1 200-1 450	Limestone and Anhydrite
	DEVONIAN			THREE FORKS	0-100	Shale, Siltstone, and Dolomite
				BIRDBEAR	0-60	Dolomite
				DUPEROW	170-250	Interbedded Dolomite and Limestone
				SOURIS RIVER	0-100	Interbedded Dolomite and Limestone
				DAWSON BAY	0-30	Dolomite and Limestone
				PRAIRIE	0-20	Limestone and Anhydrite
				WINNIPEGOSIS	0-120	Limestone and Dolomite
	SILURIAN	TIPPECANOE		INTERLAKE	220-330	Dolomite
				STONEWALL	70-110	Dolomite
	ORDOVICIAN			STONY MOUNTAIN FM.	140-160	Argillaceous Limestone
				RED RIVER	525-595	Limestone and Dolomite
			WINNIPEG GROUP	ROUGHLOCK	5-40	Calcareous Shale and Siltstone
				ICEBOX	85-115	Shale
				BLACK ISLAND	0-25	Sandstone
	CAMBRIAN	SAUK		DEADWOOD	385-750	Limestone, Shale, and Sandstone
		PRECAMBRIAN ROCKS				

Figure 5. Stratigraphic column for Adams and Bowman Counties.

Absaroka, Zuni, and Tejas. Rocks of the upper two sequences are present near or at the surface in this area.

Sauk Sequence

The Sauk Sequence is represented in North Dakota by rocks of the Deadwood Formation. Only three test holes in these counties penetrate this formation, and only one penetrates a complete section; but based on wells in Montana, South Dakota, and adjacent North Dakota counties, the Deadwood ranges from about 380 to 750 feet thick in this area. The thinnest section is in eastern Adams County. Based on the test holes in these and adjacent areas, the lower 250 to 300 feet is mostly sand and shale, while the upper 300 to 450 feet is mostly limestone and shale. The section is Upper Cambrian to Lower Ordovician in age.

Tippecanoe Sequence

The Tippecanoe Sequence began with deposition of clastics of the Winnipeg Group (Middle Ordovician) followed by carbonates with minor amounts of evaporites of the Red River Formation (Middle to Upper Ordovician). Since most of the oil production in Bowman County is from the upper part of the Red River Formation most of the oil exploration tests penetrate this section. Overlying the Red River Formation is the argillaceous limestone and limestone of the Stony Mountain Formation (Upper Ordovician) followed by dolomites of the Stonewall Formation (Upper Ordovician to Lower Silurian) and Interlake Formation (Lower to Middle Silurian). Deposition seems to have been continuous from Middle Ordovician through Middle Silurian time. The preserved sedimentary section is about 900 to 1 350 feet thick with the thickest section in northwestern Adams County reflecting the position of this area relative to the subsiding Williston Basin.

Kaskaskia Sequence

The Kaskaskia Sequence began with deposition of thin carbonate and evaporite deposits of the Winnipegosis, Prairie, Dawson Bay, and Souris River Formations representing deposits near the margin of the southward-advancing Middle Devonian sea. These formations are absent along the Cedar Creek Anticline and thicken northward from their margins. The Duperow Formation (Upper Devonian), consisting of interbedded limestone and dolomite, thins along the anticline but is present throughout these counties. The Birdbear and Three Forks Formations are absent in southwestern Bowman County probably due to an episode of Late Devonian erosion before the Madison Formation (Mississippian) was deposited. The lower part of the Madison is a fossiliferous, fragmental limestone with silicious and argillaceous zones. The upper part is mostly fine-grained or oolitic limestone, dolomitic in part, with some beds of anhydrite. The Big Snowy Group (Upper Mississippian) represents a return to clastic deposition with silt and shale, then limestone, then sandstone in the Kibbey Formation and then variegated shale of the Otter Formation. Rocks of this sequence range in thickness from about 1 700 to 2 200 feet also reflecting the position of this area relative to the Williston Basin with the thickest accumulations in northeastern Bowman and northwestern Adams Counties.

Absaroka Sequence

The initial Absaroka Sequence strata are mudstone and sandstone of the Tyler Formation (Pennsylvanian) overlain by alternating carbonates and sandstones of the Amsden and Minnelusa Formations (Pennsylvanian). These are overlain by red siltstone and shale of the Opeche Formation (Permian), then limestone of the Minnekahta Formation (Permian), then redbeds and halite of the Spearfish Formation (Permian to Triassic). Rocks of this sequence thicken westward from about 750 feet in eastern Adams County to about 1 400 feet in western Bowman County.

Zuni Sequence

The Zuni Sequence began with deposition of shale, carbonates, and evaporites of the Piper Formation (Middle Jurassic) followed by fine-grained clastics of the marine Sundance and nonmarine Morrison Formations (Middle to Upper Jurassic). At the base of the Cretaceous is the nonmarine to marine Lakota-Fall River interval consisting of interbedded sand and shale. The sand is a saline aquifer, which in this area is present at depths ranging from about 3 750 feet along the Cedar Creek Anticline to about 5 250 feet in northeastern Bowman and northwestern Adams Counties. The Newcastle or "Muddy" sand is present in some areas, and, where present, it also is a saline aquifer. The rest of the Cretaceous formations upward through the Niobrara are marine shales. The Pierre Formation, which overlies the Niobrara, is a dark-gray marine shale except for a sandstone tongue, the Eagle, which is present in western Bowman County. Most of the Pierre is present only in the subsurface, but the upper few hundred feet are exposed along the Cedar Creek Anticline. The predominantly marine rocks of this sequence (i.e., Pierre and older), generally thicken westward from about 3 600 feet in eastern Adams County to 4 800 feet in western Bowman County. Formations of the Zuni Sequence above the Pierre are present at the surface as well as the subsurface and will be treated in greater detail.

Tejas Sequence

The Tejas Sequence is represented by small erosional remnants of the White River Group in two areas of these counties and alluvium along the drainages. These deposits will be discussed as surface-subsurface units.

SURFACE-SUBSURFACE STRATIGRAPHY

Pierre Formation

The Pierre Formation is exposed in Tps129 to 132N, Rs106 and 107W along the axis of the northwest-southeast trending Cedar Creek Anticline. This area is characterized by gentle slopes with sparse vegetation on the "gumbo soils" which have developed on the gray shale. The shale is dark gray when wet and light gray when dry. The contact with the overlying Fox Hills Formation is transitional from a silty shale to a shaly siltstone and silty sandstone. Recognition at the surface is aided by the brownish weathering colors of the Fox Hills with the contact placed at the gray-brown color contact. A good exposure of the contact is the roadcut (fig. 6) in NW¼ sec 4, T131N, R106W. The transitional zone is marked in the subsurface by a gradual shift on the self-potential and resistivity logs; the absence of the weathering color changes makes precise placement of the contact difficult. In practice, the top of the Pierre is generally placed where the resistivity is low and approaching a straight line; the overlying unit is assumed to be equivalent to the brownish weathering transition zone of the surface sections.

Fox Hills Formation

The Fox Hills Formation is a brackish water to marine deposit which crops out in a narrow band along the exposures of the Pierre Formation in southwestern Bowman County. Hares (1928, p. 17) divided the Fox Hills Formation of this area into two units: a lower unnamed member and an upper Colgate sandstone member. He gave a thickness of about 85 feet for the entire formation. He noted a transitional nature and the difficulty of consistently picking the same stratigraphic horizon as the lower contact. Feldmann (1972, pl. 1) generally agreed with Hares' interpretations in this area using Colgate for the upper unit, but used the term Timber Lake for the lower member.

Waage (1968) studied the Fox Hills in outcrop areas of South Dakota extending into south-central North Dakota. He reviewed usage of Fox Hills and proposed a reference area and subdivision into three members with their type sections in South Dakota. In the lower Fox Hills he named the Trail City as a clayey silt and clayey sand member overlain by sandstone of the Timber Lake. He showed the Trail City thinning northeastward while his Timber Lake Member thinned southwestward so that in the western part of his study area the Trail City Member was overlain by upper Fox Hills which he designated as the Iron

Figure 6. Westward facing exposure of the contact between the Pierre and Fox Hills Formations in a roadcut located in NW¼ sec 4, T131N, R106W.

Lightning Member. He divided the Iron Lightning into Bullhead and Colgate lithofacies. The Bullhead lithofacies was described as thinly interbedded sand, silt, and clay; this unit has been referred to as the "banded beds" in North Dakota (Laird and Mitchell, 1942). The Colgate lithofacies was described as sand beds either at the top or within the upper Fox Hills; those at the top were described as white or grayish white as much as 60 feet thick, while those within the Bullhead lithofacies rarely exceed 20 feet. Most workers have considered Colgate to be restricted to sand at the top of the Fox Hills, but have, as Waage noted, left the impression that it is a continuous sand.

The best exposure of Fox Hills strata in this area is the roadcut in NW¼, sec 4, T131N, R106W. At this locality the transition zone of shaly silt to silty sand is about six feet thick and is overlain by 32 feet of light-yellowish-brown, fine-grained sandstone with some thin interbeds of moderate-brown shale.

Feldmann referred all of these strata to his Timber Lake Member, but if the type area terminology is to be extended into the subsurface, the transitional beds would probably be equivalent to the Trail City Member. About 60 feet of Fox Hills is present at this locality with 10 to 15 feet of light-gray sandstone of the Colgate exposed near the top of the hill south of the photo (fig. 6). In other nearby areas the Colgate Member is better exposed and 40 to 45 feet of light-gray to light-yellowish brown, fine- to medium-grained sandstone is generally present.

The contact of the Fox Hills with the overlying Hell Creek Formation has been interpreted as gradational in some areas and as a minor unconformity in other areas. In most of the exposures in Bowman County the contact seems to be slightly erosional with carbonaceous sands and clays of the Hell Creek lying on an undulating surface of Colgate sandstone (fig. 7).

The Fox Hills-Hell Creek contact is difficult to place with certainty in the subsurface as the similar lithologies, alternating sand, silt, and clay beds, have similar electric log characteristics. The general practice has been to place the contact at a prominent sand bed and then to refer to that sand as the Colgate. It has also been the practice to show a relatively rapid thickening from the thin (80 to 100 feet) surface sections measured along the Cedar Creek Anticline into the subsurface and then to recognize a thickness of 250 to 350 feet for most of western North Dakota (Cvancara, 1976, pl. 4). This is based partially on surface measurements which show around 280 to 320 feet of Fox Hills in the Missouri Valley area in Sioux and Emmons Counties. There are no surface exposures to provide a clue to thickness variations to the north, but density logs now available indicate northward thinning of the non-lignite-bearing strata of the Fox Hills-Hell Creek section.

Three North Dakota State Water Commission test holes and logs from three commercial water wells that penetrated the Pierre Formation are included in the basic data report. Most of the oil tests in these counties are drilled to the Red River Formation so they set surface casing through most of the post-Pierre strata and do not run logs through the casing. However, electric logs are available for about 16 tests which set less than 250 feet of casing. These logs provide information for most of the post-Pierre section.

Based on studies of available logs it seems likely that the Fox Hills Formation gradually thickens eastward across Bowman and Adams Counties from about 80 to 100 feet in the surface sections to about 230 feet in eastern Adams County (pl. 2). Recognition of the surface subdivisions in the subsurface is uncertain, but a silty shale transition zone, which thickens eastward, may tentatively be termed the Trail City Member. In western Bowman County, the transition zone is overlain by a predominantly sand section which can be divided into Timber

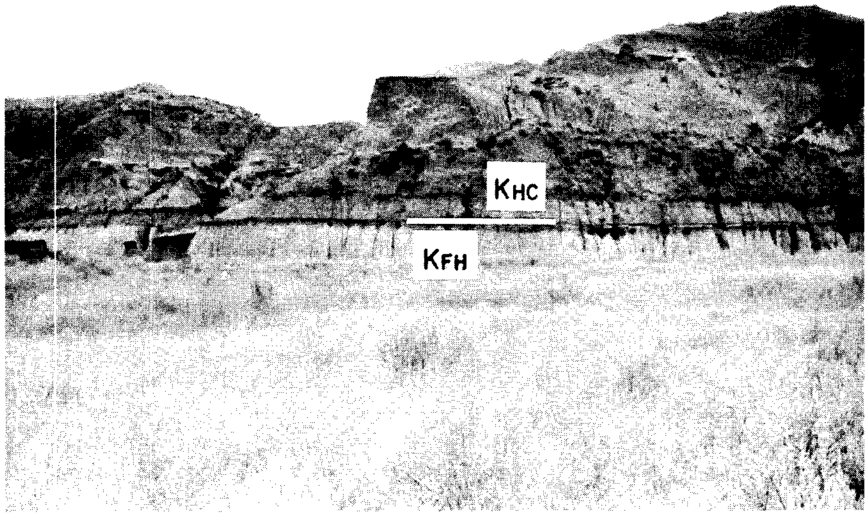

Figure 7. Westward facing exposure of the contact between the Fox Hills and Hell Creek Formations located in E½ of sec 30, T132N, R107W.

Lake and Colgate Members similar to the surface sections. A sand of variable thickness at the top of the Fox Hills in the subsurface may be referred to the Colgate Member. Eastward across Adams County silt and shale increase until they are the predominant lithology. In this area the alternating silt, clay, and sand beds may be referred to the Bullhead Member which becomes sandier and pinches out westward in central Bowman County.

Hell Creek Formation

Hares referred to about 575 feet of dark-gray and brown sandstone and shale beds overlying the Fox Hills Formation as the Hell Creek Member of the Lance Formation of (?) Tertiary age. He (Hares, 1928, p. 22) characterizes the Hell Creek as "decidedly heterogenous structurally, cross-bedded, and seemingly orderless." Subsequent studies have shown that dinosaur remains are limited to the Hell Creek strata so the Tertiary-Cretaceous boundary is now recognized at the top of the Hell Creek and the rank has been raised to formation.

Frye (1969) studied the Hell Creek Formation and divided it into five members in the Little Missouri valley area. In ascending order they were named: Little Beaver Creek, Marmarth, Bacon Creek, Huff, and Pretty Butte Members. The Little Beaver Creek Member was described as lignitic sediments consisting of channel sandstones, shales, and smaller sandstone bodies. The Marmarth and Huff Members were characterized as mainly sandstone units thought to be channel deposits of large rivers. The Bacon Creek Member was described as bentonitic shale, bentonite, lignitic shales, and occasional channel sandstones. The Pretty Butte Member was described as bentonite and bentonitic shale with small channel sandstones. Only the Little Beaver Creek Member has its type section in these counties and each of the members has its type section at a different locality. At their type sections in Slope and Bowman Counties, thicknesses of the members were measured as: Pretty Butte--42.5, Bacon Creek--117, Marmarth--74, and Little Beaver Creek--105 feet. The Huff Member, the type section of which is in Morton County, was measured as 85 to 100 feet thick in the Little Missouri area. In his composite section, Frye shows a thickness of about 450 feet of Hell Creek and about 100 feet of Fox Hills for the Marmarth area.

Examination of Frye's type sections and the numerous good exposures in these and adjacent counties led to the conclusion that it would be difficult, if not impossible, to use these members as map units. The Hell Creek strata are characterized by relatively rapid facies changes and a lack of bed continuity so that as soon as one gets away from his type sections it is difficult to be sure where one is in the section unless either the Fox Hills or the Ludlow is exposed at that locality.

The Hell Creek is well exposed in the badlands along the Little Missouri River south of Marmarth, and numerous sections were measured on each side of the river. Generally the formation may be characterized as drab colored and lacking orderly bedding; i.e., lithologic units are not laterally persistent. Vertical changes are also generally rapid. Channel sands are sometimes 40 to 60 feet thick, but in most measured sections most of the sands are 10 to 20 feet thick with beds less than 10 feet common. Thin beds of silt and clay, often carbonaceous or bentonitic, account for most of the intervening strata. Lignitic shales and lignite are present, but not common, and were noted mostly in the lower 100 feet of the formation. Lignites, where present, are generally one to three feet thick and lack lateral persistence. Cross-bedding is common in the thicker sand beds as are ferruginous nodules and concretions of various sizes. Texture is generally fine- to medium-grained in the thicker sands and very fine to fine-grained in the thinner beds. Generally the sands include conspicuous amounts of carbonaceous material as well as significant amounts of silt and clay.

The contact with the overlying Ludlow Formation is placed at the top of carbonaceous and bentonitic shales, which contain

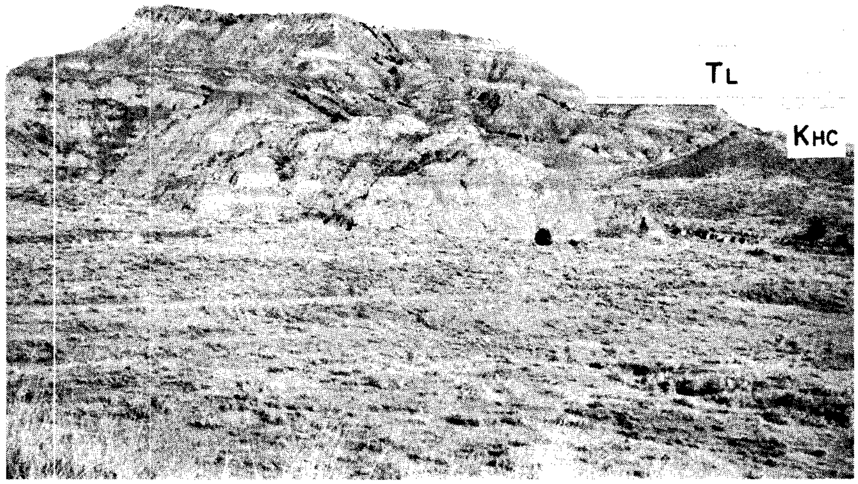

Figure 8. Southwestward facing exposure of the contact between the Hell Creek and Ludlow Formations located in NW¼ sec 21, T132N, R105W.

dinosaur fragments at various localities. Generally a thin, one- to two-foot-thick lignite is present as the basal bed of the Ludlow. This lignite is overlain by alternating, laterally persistent beds of silt, clay, sand, and lignite. The lateral persistence of these beds is in marked contrast to the underlying strata (fig. 8), and even where lignite is absent the contact can be readily recognized. The carbonaceous and bentonitic shales have been referred to as the Pretty Butte Member, but since the other subdivisions are not useful there is little utility in retaining this term either.

A complete exposure of the Hell Creek Formation is not present at any one locality. This, together with lack of lateral persistence of beds, makes determination of total thickness of the formation from surface sections difficult. Based on subsurface information near the outcrop areas a thickness of 450 to 475 feet seems appropriate for the Hell Creek Formation in western Bowman County.

In the subsurface, the Hell Creek apparently has the same lack of continuity of beds as is noted in surface sections. Along the line of cross section (pl. 2), sand accounts for about 40 to 45 percent of the total thickness with most holes having 15 to 20 beds of sand. Most of these beds are less than 20 feet thick, but each hole usually has two or three beds greater than 20 feet and one 70-foot bed was noted (NDGS 4529). The sandiest part of the Hell Creek is variously in the upper part (NDGS 4529), the middle part (NDGS 4473), or the lower part (NDWC 4313). There do not appear to be any beds which are correlatable for any significant distance within the Hell Creek. The top of the Hell Creek Formation in the subsurface was identified by using density logs to pick the lowest lignite beds in NDWC test holes 4312 and 4313 and placing the top of the Hell Creek on what are believed to be carbonaceous and bentonitic shales. This unit was then traced westward on the electric logs to the outcrop area.

Ludlow Formation

Lloyd and Hares (1915) introduced the term Ludlow as a lignitic member between the Cannonball and Hell Creek Members of the Lance Formation in northwestern South Dakota and southwestern North Dakota with a type section near Ludlow, South Dakota. Hares (1928) established North Dakota usage of Ludlow while noting a change in characteristics and color between the Ludlow and Little Missouri areas of the strata assigned to this member. He recognized an intertonguing relationship between the Ludlow and Cannonball Members in the Slope County area and noted the stratigraphic position of the marine and brackish water faunas relative to the T Cross lignite and his overlying Tongue River Formation. Moore (1976) reviewed usage of Ludlow and, based on his fieldwork in Slope County, made a slight adjustment of Hares' contact between the Ludlow and Tongue River Formations and then divided the strata with the interval from the Hell Creek to the T Cross bed as his lower Ludlow and the interval from the T Cross bed to his "white siliceous bed" as upper Ludlow. Clayton and others (1977) reviewed the various usages of Ludlow in different areas and redefined its usage in North Dakota restricting Ludlow to the nonmarine strata between the Hell Creek and Cannonball Formations where the Cannonball is present as in Adams and eastern Bowman Counties and between the Hell Creek and the T Cross bed in western Bowman County. As thus restricted, it is equivalent to Moore's lower Ludlow or Frye's Tullock Member.

As thus defined, the Ludlow Formation extends as an outcrop band generally two to four miles wide through Rs104 and 105W. It consists of drab-colored, alternating, laterally-persistent beds of lignite, sand, silt, and clay. A complete section is not exposed at any one locality, but a nearly complete section is exposed on the south side of Sunset Butte (SE¼, sec 24, T131N, R105W) where I measured about 166 feet of Ludlow. At this locality the thickest sand is about 20 feet and the thickest lignite is near the middle of the formation where a five-foot bed with carbonaceous shale breaks is present. Other areas of good exposures of the basal contact and significant portions of the Ludlow are near U.S. Highway 12 in sec 8, T132N, R105W and in the SW¼, sec 1, T129W, R105W. In Slope County, Frye (1969, p. 50-52) measured a complete section of Tullock (= Ludlow of this report) at Pretty Rock Butte as 160 feet.

The upper contact of the Ludlow is poorly exposed in most areas of these counties. In western Bowman County scattered exposures of the T Cross lignite or associated clinker are found and interpolation was used between these exposures. In eastern Bowman and southwestern Adams Counties the contact is placed below the thin-bedded silts, sands, and shales of the Cannonball Formation. Although the Ludlow is generally drab shades of brown and gray, the upper portion has some yellowish beds which are more prominent in the area near Bowman-Haley Dam.

The lateral continuity of beds observed in surface sections is not readily apparent on the electric logs, but some indication of thin alternating beds of sand and fine clastics or lignites may be noted. The Ludlow Formation generally lacks thick channel sands. The thickness assigned to the Ludlow in NDWC test holes 4312 and 4313 is about 300 feet. The top of the Ludlow was placed (pl. 2) at a lignite bed that is overlain by mudstone of the Cannonball. This horizon was then projected westward to the outcrop area, but it is difficult in the absence of density and gamma ray logs to trace lignite beds through the subsurface so it may be that a lower lignite should be correlated with the T Cross bed.

Cannonball Formation

Lloyd (1914) introduced the term Cannonball to apply to the marine strata exposed along the Cannonball River in Grant County. These strata, which were originally proposed as the upper member of the Lance Formation, have generally been thought to be the marine equivalent of the nonmarine Ludlow Formation and an intertonguing relationship has generally been implied. Nonmarine strata overlying the Cannonball were placed in the Tongue River Formation except in Slope County where some nonmarine strata overlying brackish water tongues assigned to the Cannonball have been included in the Ludlow. Current thought (Clayton and others, 1977) is that intertonguing relationships of the marine and nonmarine strata should be revised to recognize these relationships for both the transgressive and regressive phases of the Paleocene seas. The transgressive phase has an eastward-thinning wedge of nonmarine strata between the Cannonball and Hell Creek Formations which should be assigned to the Ludlow Formation whereas an eastward-thinning wedge of nonmarine strata between the Cannonball and Tongue River Formations representing the regressive phase should be assigned to the Slope Formation.

Cvancara (1976, pl. 4) shows a thickness of 350 feet for the Cannonball Formation in northeastern Adams County, thinning south and westward to about 200 feet at the South Dakota border in eastern Adams County and to about 100 feet in the southwestern corner of the county. He characterizes the Cannonball as consisting of two principal lithologies: sandstone and mudstone. In surface studies in Morton County he recognizes three laterally-traceable sandstones with the middle sandstone traceable into Grant County and maybe into north-central Adams County.

Fenner (1976) obtained foraminifera from the Cannonball in seven of the North Dakota Water Commission test holes in these counties. Based on his results and log analyses, the Cannonball Formation is about 275 feet thick in eastern Adams County, thinning westward to a depositional edge in central Bowman County. The thinning westward of the Cannonball is compensated by thickening of the Slope and Ludlow Formations.

Scattered exposures of the upper 200 feet of Cannonball occur along Cedar Creek and its tributaries. There are also scattered exposures along the tributaries of the Grand River, Lightning, Buffalo, Willow, and Flat Creeks. Generally, only small portions of the Cannonball are exposed at any one locality. In these areas it consists of thin-bedded, light-yellowish-brown, moderate-brown and gray mudstone, siltstone, and sandstone.

The contacts with the adjacent formations are not well exposed, but the thin-bedded, fine-grained clastics are overlain by sand and then by alternating sand, silt, clay, and lignite of the nonmarine facies. The upper contact has usually been placed at the base of sand, which was then termed the "basal Tongue River sand"; however, the first sand appears to be a marine sand representing the regressive phase of the Paleocene seas. The contact with the underlying nonmarine strata is present in T129N, Rs98-100W, where the thin-bedded marine strata are exposed in several roadcuts.

In the subsurface the Cannonball is characterized by a uniform self-potential and resistivity pattern which can be correlated between logs representing a recognizable continuity of beds. The mudstones and siltstones have yielded forams from NDWC 4312 which were studied (Fenner, 1976) and which aided the subsurface interpretations. The Cannonball has an intertonguing relationship to nonmarine strata above the T Cross lignite in test hole NDWC 4312 and extending westward at least as far as NDGS 4448 (pl. 2). There is also an indication that the Cannonball may intertongue with the Ludlow in eastern Adams County, but there is no foraminiferal data to support it. The middle bench sandstone of the surface sections may be the sandstone from a depth of 200 to 240 feet in NDWC 4312.

Figure 9. Exposure of "white marker zone" at top of Slope Formation south of U.S. Highway 12 in SW sec 10, T131N, R102W.

Slope Formation

The Slope Formation was introduced by Clayton and others (1977) to refer to the nonmarine strata overlying the Cannonball Formation (or, where Cannonball is absent, the T Cross bed) and underlying a "white marker zone." These strata had previously been placed in either the Ludlow or Tongue River Formation. Generally the strata herein referred to the Slope Formation in western and central Bowman County were previously placed in the upper Ludlow, while those in easternmost Bowman and in Adams County were placed in the Tongue River Formation.

These strata are generally poorly exposed across the gently rolling uplands, and only small portions of the formation are exposed at any one locality. The upper contact occurs at a prominent "white marker zone," which can be seen at scattered exposures (fig. 9) across both counties. This zone is interpreted as a weathering zone variously developed on sand, silt, or clay and usually capped by a few feet of yellowish-gray, siliceous material. The lower contact is recognized in scattered exposures of the T Cross lignite or clinker in the western area. In Adams County, it is placed above a sand which is thought to be a shoreline sand of the regressive phase of the Cannonball seas. In the area of the Bowman-Haley Dam (T129N, Rs98-100W), near the westernmost exposures of Cannonball strata, some nonmarine strata mapped as Ludlow may be a lower tongue of the Slope Formation, but the absence of density and gamma ray logs to trace the T Cross bed makes it difficult to place the Slope-Ludlow contact in this area. For this reason, previous practice of placing all nonmarine strata below the Cannonball in the Ludlow was retained.

The Slope Formation consists of alternating beds of sand, silt, clay, lignite, and sandstone. Colors range from drab browns and grays to bright shades of yellow and light grays. At its type section in Slope County it is about 300 feet thick with two tongues of Cannonball present. Surface measurements cannot be used to determine the thickness in these counties. There is a general lack of gamma ray or density logs of this section, and the oil tests set surface casing through much or all of the Slope Formation so subsurface information is sparse. Projections westward from NDWC 4312 and 4313 indicate a thickness of about 250 feet in the Rhame-Bowman area. The Slope Formation thins eastward as it intertongues with the Cannonball with the upper tongue thinning to 60 to 80 feet thick in Adams County.

Bullion Creek Formation

A distinctively light- or buff-colored unit within the lignite-bearing strata has long been recognized in the area of badlands along the Little Missouri River. Leonard (1908, pl. XII) referred to these strata as the Middle Fort Union. Taff (1909, p. 129) introduced the term Tongue River to refer to Tertiary coal-bearing strata in northeastern Wyoming. Thom and Dobbin (1924, p. 494) in their regional study extended the term Tongue River to North Dakota using it for strata approximately equivalent to Leonard's Middle Fort Union. Thom and Dobbin correlated Leonard's Upper Fort Union with the Wasatch of Wyoming. When it was determined that Leonard's Upper Fort Union was Paleocene in age these strata were referred to as the Sentinel Butte member or facies of the Tongue River. Royse (1967) elevated the Sentinel Butte to a formation and restricted Tongue River to the light- or buff-colored unit equivalent to Leonard's Middle Fort Union. As recently used in North Dakota, Tongue River has usually been restricted to these strata.

The upper contact of the light- or buff-colored strata has been placed at a lignite bed variously labeled the F (Leonard and Smith, 1909), R (Leonard, 1925), HT Butte (Hares, 1928), or L bed. The lower contact was placed at a sandstone below the H bed by Hares (1928) in the Slope County area while to the east the top of the Cannonball Formation was used as the base of the Tongue River. Hares (1928, p. 34) places the siliceous bed ("white marker zone"), herein recognized as the base of the light- or buff-colored unit, about 60 feet or more above the base of his Tongue River. In the North Cave Hills, Pipiringos and others (1965, A6) show the Tongue River on Ludlow; however, examination of the exposures show sandstone of marine or brackish affinities and the "white marker zone" included in their Tongue River Formation. Hares (1928, p. 35) also noted the siliceous bed ("white marker zone") about 46 feet below the White River Formation and about 250 feet above the base of the Fort Union (= Tongue River) in that area.

It now appears that in South Dakota the term Tongue River is used to refer to the stratigraphic interval, which in North Dakota was referred to as Tongue River and Upper Ludlow (now Slope); while in Montana and Wyoming, the term Tongue River is used for strata that in North Dakota have been referred to as Tongue River and Sentinel Butte. To avoid the confusion of applying the same name to different strata in different areas and to refine the lower contact so that the base of the light- or buff-colored strata is at the same horizon (the "white marker zone") in all areas of North Dakota, Clayton and others (1977) introduced the term Bullion Creek to apply to the light- or buff-colored strata in North Dakota. The type section was selected in southeastern Golden Valley County where the formation is about 300 feet thick.

Interest in the Bullion Creek has been primarily for its lignite potential. The usual procedure has been to measure and name the lignite beds and place them in their stratigraphic position based on intervals between lignites. Hares (1928, p. 47) provides a generalized section of the Bullion Creek (his Tongue River) in the surface sections along the Little Missouri River. He designates five lignite beds, which in ascending order are: H, Hansen, Harmon, Garner Creek, and Meyer beds. The H bed seems to be discontinuous and, where present, it is associated with the siliceous bed or "white marker zone." The Harmon and Hansen beds are persistent, although they often are split by fine-grained clastics so that in some areas they are lignite zones rather than one continuous bed (pl. 3). In his general column Hares shows the Harmon as about 50 to 60 feet above his H bed. In his measured section near Rhame (p. 33) he placed the Harmon about 140 feet above the siliceous bed. In the subsurface the base of the Harmon zone in test hole G440-L2 is at 253 feet and the test hole stopped at 347 feet on a siliceous bed, which is probably the "white marker zone," so it is about 90 feet above the base of the Bullion Creek at that locality. The lignite bed at 54 to 60 feet is correlated as the HT Butte bed based on test holes in Slope and Hettinger Counties, so the Bullion Creek is about 300 feet thick in this area. Correlation of the Garner Creek and Meyer beds is difficult, but Garner Creek has been used in Hettinger County where Owen (in preparation) also used Nomad for a bed between the Harmon and Garner Creek beds and a Coal Bank Creek bed in the approximate position of the Meyer bed. Lignite beds above the Harmon bed in test hole G440-L2 appear to be correlative northward with beds that have been named in Hettinger County. Lignite beds vary rapidly in thickness and continuity, as can be seen from the cross section (pl. 3), so these correlations are somewhat tenuous, but they provide a stratigraphic framework for reference.

The characteristic alternation of sand, silt, clay, and lignite noted in surface exposures of the Bullion Creek Formation is also apparent in test holes G440-L1, -L2, and -L75 (pl. 3) where nearly complete sections of this formation are present. In this area the section below the Harmon bed is predominantly clay and silt, although some sand is present. The only test holes with channel-type sands are G169-17, where the Harmon bed is overlain by 65 feet of sand and the interval from 0 to 25 feet may be another channel sand, and G169-31 where the interval from a depth of 66 to 110 feet in the upper part of the Bullion Creek may be a channel deposit. Otherwise, the formation is characterized by alternating beds of sand, silt, clay, and lignite with the thickest sands being about 10 to 12 feet thick.

Sentinel Butte Formation

Leonard (1908) introduced the term Sentinel Butte to refer to a group of coal beds in the dark-colored upper part of the Fort Union. Hares (1928) used Sentinel Butte as a member of the Fort Union to refer to the somber-colored beds above the HT Butte bed. Subsequently, Sentinel Butte was used as either a member or facies of the Tongue River until Royse (1967) elevated Sentinel Butte to formation; and it has generally been recognized as such since that time.

Areas of Sentinel Butte are limited to some of the drainage divide areas of northern Bowman and Adams Counties where the strata are poorly exposed. Subsurface data from test holes in adjacent counties together with topographic control have been used to project the HT Butte bed through the area of poor exposures and sparse subsurface information. A complete section is present at Whetstone Buttes where the overlying White River Group lies unconformably on the Sentinel Butte strata, but the upper contact is in a grassy area and is not exposed. The base of the formation should be at an elevation of around 2 825 to 2 850 feet based on test hole G440-L2, so the Sentinel Butte Formation may be as much as 200 to 250 feet thick at that locality.

White River Group

Sediments referred to the White River Group are limited to erosional remnants in two small areas within these counties. The best exposures are in T132N, R98W, where conglomeratic sandstones cap the Whetstone Buttes. The lower contact is grassed over so the thickness and character of the entire group was not determined. There is also a remnant of sandstone a few feet thick on the top of the Medicine Pole Hills in sec 30, T131N, R104W, which probably belongs to this group.

Alluvium

Recent alluvium is present at the surface on flood plains of present drainage. Auger holes on the flood plain of the Little Missouri River show 15 to 30 feet of mostly fine to very fine sediment on the surface overlying fine- to medium-grained sand with minor gravel in Tps129 to 130N. In Tps131 and 132N gravel is generally present and the alluvium thickens to 25 to 40 feet. Auger holes along the Grand River in T129N, R99W, show 12 to 22 feet of alluvium with some gravel present in that area. Test holes along Cedar Creek indicate 15 to 20 feet of alluvium along that drainage. Duck Creek and other small tributaries of the major drainage also have a few feet of alluvium along their course.

There are a few remnants of a high terrace along the Little Missouri River. These remnants are characterized by flat surfaces which often have a few feet of poorly sorted gravel overlain by a foot or two of silt and very fine grained sand.

GEOLOGIC HISTORY

The geologic history of this area as deciphered from the sedimentary record is one of five major episodes of marine transgression across the area represented by the Sauk through Zuni Sequences with intervening episodes of erosion. Since deposition of the Zuni sediments the area has been subject to erosion and terrestrial deposition with erosion being the dominant process. High elevation gravels along the Little Missouri and elsewhere in these counties represent deposits of early streams which drained north and eastward toward Hudson Bay during the late Tertiary. The clinker, or "scoria," formed during this episode as lignite beds were exposed and then burned back from the outcrops. Glaciation of the eastern part of the state during the Pleistocene blocked the northeastward drainage forming the ice-marginal Missouri River. During and after melting of the ice the Little Missouri and other drainages became tributaries of the Missouri River. The eastward flowing streams are headwaters and are not affected much by the change in base level, but the lower base level of the postglacial Little Missouri River led to the development of badlands along this stream. Badlands continue to form as the stream continues to adjust to the new base level.

Lignite

Lignite beds are present in the Ludlow, Slope, Bullion Creek, and Sentinel Butte Formations. Their widespread occurrence near the surface provided convenient fuel for early settlers, and at one time there were many small mines in these counties. State Coal Mine Inspectors' reports indicate that most of the lignite was produced from underground or slope mines and that production peaked at around 80 000 tons annually in Adams County in the early 1920s. In the late 20s a strip mine was opened in Bowman County, and in 1932 stripping began in Adams County. However, it was not until Dakota Collieries near Haynes began stripping operations in 1945 that strip-mine production exceeded underground production. The decline in use of lignite for domestic purposes led to closure of mines and by 1950 the only mines in the two counties were four strip mines. Development of the Peerless mine near Gascoyne in 1950 led to Bowman County production exceeding that of Adams County, and recent expansion of the Gascoyne mine makes this a major producing area in the state.

Early lignite studies (Leonard, 1908, 1925; Lloyd, 1914; Hares, 1928) were based on surface studies and information obtained from active mines. The lignite beds were either given letter designations or names derived from mines or nearby towns and placed in stratigraphic position based on thickness of intervening beds.

Leonard (1908, 1925) used letter designations for lignite beds of the Fort Union in the Little Missouri area dividing them into groups of beds which were given geographic names. In his discussion of Bowman County he also used Bowman, Harmon, or Sand Creek, and Scranton beds for lignite beds in the eastern part of the county placing them in stratigraphic position (Leonard, 1925, fig. 7). He used the Haynes bed, introduced by Lloyd (1914), in his Adams County discussion.

Hares (1928) prepared a generalized stratigraphic section for western Bowman and Slope Counties using names or letters for the coal beds. In the Ludlow, named beds in ascending order were: Cannonball, Beta, T Cross, and Yule (or Ives) with some intervening beds designated by letters; in the Tongue River he recognized H, Hansen, Harmon, Garner Creek, and Meyer beds below the HT Butte bed; he also showed the Bullion Butte bed high in the Sentinel Butte.

Brant (1953) made estimates of the lignite resources of these counties based primarily on extrapolation of previously published information. He recognized 17 lignite beds in estimating 7 021 million tons of lignite reserves in Bowman County. In Adams County, he recognized five beds and estimated reserves at 1 856 million tons.

Kepferle and Culbertson (1955), using subsurface information, outlined three areas of possible strippable reserves in these counties. One was the active Gascoyne area, a second was north of Bowman extending northward into Slope County, and a third one was northwest of Rhame, also extending northward into Slope County. The Rhame deposit was in the T Cross bed. They placed the other two deposits in the Harmon bed, which they recognized as equivalent to the Bowman and Scranton beds of previous workers. They placed the Harmon bed 100 to 140 feet above the base of the Tongue River Formation and 5 to 60 feet above the Hansen bed. They estimated strippable reserves of the Harmon bed at 273 million tons in the Gascoyne area and 228 million tons in the Bowman County portion of the Slope-Bowman deposit. They did not make an estimate for the T Cross deposit, but most of that deposit is in Slope County.

Topographic control and lignite resource evaluation test holes, which are now becoming available, provide a means for some reassessment of earlier interpretations and evaluations. Examination of logs (pl. 3) shows variations in thickness and number of beds between holes and demonstrates the difficulty of correlation of units within the Bullion Creek Formation. Test holes G169-30 and -31 demonstrate that the Harmon "zone" is the lowest significant lignite in the Bullion Creek Formation and that there are no significant beds in the Slope Formation in this area. The lignite bed from 472 to 477 feet in G169-31 may be the T Cross bed, but it is too far from other control to make such an assertion.

The test-hole information is not sufficient to refine reserve estimates, but it is sufficient to place the beds in their proper stratigraphic position. Test-hole drilling and surface studies indicate that Kepferle and Culbertson were correct in considering the Scranton and Bowman beds to be equivalent to the Harmon bed. It is now apparent that the Haynes bed is also equivalent to the Harmon bed. It now appears that in these two counties the Harmon and T Cross beds are the only beds of major economic interest.

Little subsurface information is available for the T Cross bed. The lignite resource evaluation test holes indicate that, for the Harmon bed, the areas outlined by Kepferle and Culbertson are the general area of important reserves in Bowman County. Revision of reserve estimates will depend on adjustments of stripping ratios and more drilling to provide the details of thickness variations within these deposits. Test-hole information is not sufficient to adjust estimates for Adams County, but the Harmon (= Haynes) bed appears to be the only bed of major interest in that county.

Petroleum

Natural gas has been produced from the Eagle sandstone in Bowman County since the opening of the Cedar Creek pool in

1929. The Little Missouri pool was added in 1954. These pools, producing from depths of about 1 200 to 1 700 feet, are still producing from about 20 wells. Production through 1977 was about 12 250 000 MCF.

Oil was discovered in the Red River Formation in the Little Missouri field at a depth of about 8 200 feet in 1958. The Cedar Creek Red River pool was opened in 1960. These oil and gas pools are along the crest of the Cedar Creek Anticline, a major structure trending northwest-southeast across the southwestern corner of Bowman County. Subsequent exploration has discovered eight Red River pools to the east of the axis of the structure. Cumulative production from these reservoirs has been about 17.3 million barrels as of January 1, 1978, with slightly over ten million barrels from the Cedar Creek field, which during the last half of 1976 was the tenth largest producing field in the state.

There has been no oil production from Adams County, but there has not been much exploration either, so the potential has not been determined.

Sand and Gravel

Two types of gravel deposits are found in Adams and Bowman Counties. One type consists of deposits along the present drainage; however, these are generally small, poorly sorted, and may be wet.

The second type are the high terrace remnants along the Little Missouri or on ridges on the upland surfaces. Their presence on the upland ridge results from the good permeability which has allowed percolation of precipitation through these sediments, so they are relatively resistant to erosion compared to the bedrock materials. These are deposits of ancient streams that flowed through the area during previous erosional cycles.

Uranium

Uranium has been reported from lignite beds in some drill holes in the Medicine Pole Hills area (Zeller and Schopf, 1959, table 4) with a range of .002 to .080 percent in ash for 22 analyses from four cores. The source of the uranium is generally ascribed to the White River Group with potential ore deposits resulting from leaching and then concentration in favorable underlying sediments. The presence of White River Group on Whetstone Buttes indicates that at one time most of these counties probably had a cover of White River sediment to provide a source of uranium. The presence of lignite and carbonaceous shales in each of the Hell Creek, Ludlow, and Slope through Sentinel Butte Formations, as well as the sandstones in these formations, are considered to be possibly favorable environments for concentration of uranium. Exploration may locate commercial quantities of uranium in these counties.

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