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Energy and Mineral Resource Assessment of the Ashland Division of the Custer National Forest, Powder River and Rosebud Counties, Southeastern Montana

by

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ABSTRACT

The U.S. Geological Survey conducted an assessment of the mineral and energy resources of the Ashland Division of the Custer National Forest. The Ashland Division comprises approximately 780 square miles (2,030 square kilometers) between the towns of Ashland and Broadus in southeastern Montana. All rocks exposed in this area are part of the Tongue River Member of the Paleocene Fort Union Formation, consisting mainly of shale, siltstone, sandstone, thick coal, clinker, and thin lenses of limestone. The study area lies in the north-central part of the Powder River Basin.

The resource wealth of the Ashland Division lands abides in enormous reserves of lignite and subbituminous coal with low sulfur and low to moderate ash content. One estimate suggests that about 42 billion short tons of non-leased federal coal occur within 3,000 ft of the surface in the Ashland Division. The entire extent of the Ashland Division is underlain by coals of the Tongue River Member; about 20 coal beds have been correlated through the area to a depth of 2,000 ft. Single coal beds are as much as 65 ft thick. The thickest coal beds of the study area include the Anderson, Dietz (or the merged Anderson-Dietz), and Knobloch beds. At least one-third of the study area contains strippable coal deposits, defined as one or more coal bed(s) of 5 ft or greater in thickness overlain by less than 200 ft of overburden. The Ashland Division contains 16 strippable coal deposits, which include several areas where thick coal seams are covered by less than 100 ft of overburden. The largest tonnages of strippable coal occur in the Ashland coal deposit, where the Knobloch coal bed is 40-58 ft thick and the Sawyer bed is 7-16 ft thick.

Thick widespread outcrops of clinker represent another abundant resource of the Ashland Division area. Clinker is a baked, fused or melted rock, usually reddish or lavender, formed by the natural burning of an underlying coal bed. Clinker in the Powder River Basin region is often mined, crushed and used locally for surfacing improved unpaved roads and as an aggregate material in paved roads. Clinker is abundant, accessible, and easy to excavate. The proximity to roads where it is needed is the primary factor in its usage.

The Ashland Division area has no record of oil or gas production despite a moderate amount of oil and gas exploration. Five prospective petroleum plays have been identified beneath the Ashland Division; they involve Lower and Upper Cretaceous strata that host producing horizons elsewhere in the Powder River Basin. These plays remain hypothetical for the Ashland Division area, which appears to lack the prominent anticlines and domes typically favorable for oil and gas accumulation.

The potential exists for undiscovered coal-bed methane, although this resource has yet to be proven or developed within the National Forest. Areas with Fort Union Formation coal beds deeper than 500 ft should have potential for coal-bed methane. Many areas of the Ashland Division meet this criteria.

No potential for metallic mineral deposits exists in the Ashland Division area. No metallic mineral deposits are known, and the geology of the area combined with the results of reconnaissance geochemical surveys reveal no indications of undiscovered deposits.

INTRODUCTION

At the request of the U.S. Forest Service, the U.S. Geological Survey (USGS) conducted an assessment of the mineral and energy resources of the Ashland Division of the Custer National Forest, located in southeastern Montana. This study contributes to a broader USGS evaluation of the undiscovered mineral resources within the full extent of the Custer and Gallatin National Forests of southern Montana (see Hammarstrom and others, 1993). These USGS assessment studies are intended to provide mineral resource information to the U.S. Forest Service for consideration in management plans for federal lands.

The Ashland Division of the Custer National Forest encompasses approximately 780 square miles (2,030 square kilometers) between the towns of Ashland (on the west) and Broadus (to the east) in southeastern Montana (fig. 1). Numerous small tracts of privately owned lands lie within the boundaries of the National Forest. For the purpose of this study, the entire area within the outside boundary of the National Forest was evaluated as a continuous tract (striped area of figure 1).

The only rocks exposed in the Ashland Division study area are those of the Tongue River Member of the Paleocene Fort Union Formation. The rocks consist mainly of shale, siltstone, sandstone, thick coal, clinker, and thin lenses of limestone. Most of these strata are poorly cemented and generally nonresistant, forming grassy and sage-covered slopes. Interbedded resistant layers form ledges and broad benches, creating bandlands topography and escarpments along the creeks. The resistant strata include massive sandstone beds cemented with calcium carbonate as well as widespread outcrops of thick clinker. Clinker is brittle rock of reddish or lavender shades found above burned coal beds. These rocks were baked and fused by the heat produced during the natural burning of the underlying coal bed.

The Ashland Division area contains enormous coal reserves. By one estimate, about 42 billion short tons of non-leased federal coal remain in the Ashland Division (to a depth of 3,000 ft). For the region that includes the Ashland Division area, about one-fourth of the coal reserve has high potential for recovery by surface mining methods ("strippable coal") (Trent, 1986). Numerous scientific and coal exploration studies completed by the U.S. Geological Survey and the Montana Bureau of Mines and Geology have included parts of the Ashland Division. Results and conclusions of these studies provide valuable information regarding the geology and coal resources of the Ashland Division area. The intent of this report is to summarize this published information and incorporate the results of a previous coal resource assessment.

Despite a moderate amount of petroleum exploration within the study area, no oil or gas reservoirs have been discovered beneath the Ashland Division lands. Although no petroleum has been discovered in the study area, several of the sedimentary rock sequences that host oil and gas elsewhere in the region are present several thousand feet beneath the Ashland Division area.

No metallic mineral deposits are known within the Ashland Division area. Neither the geology of the area nor the results of reconnaissance geochemical surveys indicate any potential for undiscovered metallic mineral concentrations.

Note to reader: All measurement units presented in this paper are given in the unit in which the measurement was made during the study or was provided by the reference. That is, to provide smoother reading, the corresponding metric-U.S. customary unit conversions are not necessarily provided simultaneously herein. References to "tons" throughout the text,

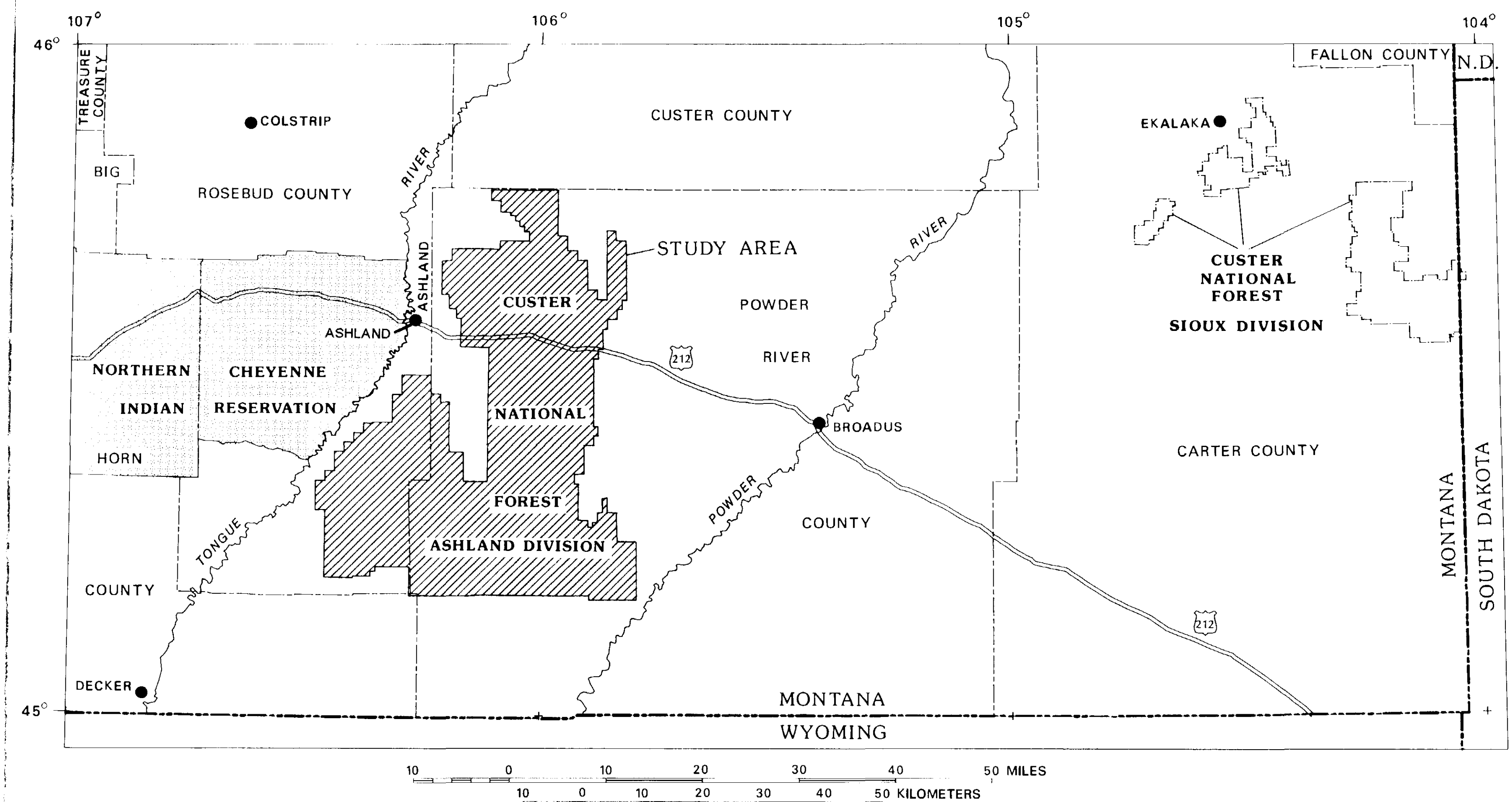

Figure 1. Map showing the location of the Ashland Division of the Custer National Forest in southeastern Montana. "N.D." indicates North Dakota.

figures, tables and appendices correspond to short tons, which is equal to 2,000 pounds. Metric tons, or tonnes (megagrams), may be calculated by multiplying short tons ("tons") by 0.9072; short tons may be calculated by multiplying metric tons by 1.102. Feet may be calculated by multiplying meters by 3.281; meters may be calculated by multiplying feet by 0.3048.

REGIONAL GEOLOGY

The Ashland Division area lies in the north-central part of the Powder River Basin, a large depositional basin of the northern Rocky Mountains located between the Black Hills of South Dakota and the Bighorn Mountains of Wyoming (fig. 2). During the Laramide Orogeny of the Late Cretaceous and early Tertiary, non-marine sediments were deposited in the basin from sources in the surrounding uplifted areas. The sedimentary rocks representing this deposition reach nearly 8,000 ft in thickness at the basin axis (Curry, 1971). All of the exposed consolidated rocks in the study area belong stratigraphically to the Tongue River Member of the Paleocene Fort Union Formation (plate 1). The Tongue River Member and underlying Tertiary sedimentary rocks of the study area dip mainly southwestward toward the basin axis at less than ½°; the basin axis trends approximately N.20°W. Modest local undulations within the regional dip are likely the result of differential compaction of strata in the Tongue River Member.

Regional stratigraphic studies show that basin subsidence was active during the deposition of the Tongue River Member. The thick coal-bearing intervals of the Tongue River Member, common to the study area and large areas of the Powder River Basin (see Denson and Crysdale, 1991), represent episodes of relatively low (tectonic) energy for the basin. The thick coal beds of the region originated as thick peat accumulations. Some of largest coal fields and thickest coal beds in the world occur in the Tertiary rocks of the Powder River Basin of Wyoming and Montana. The thick coals are especially concentrated in the eastern, more gently-dipping flank of the asymmetric basin.

The Laramide structural controls that formed the Powder River Basin and influenced the accumulation of thick peat deposits have been conceptualized by the "teeter-board" hypothesis of Kent and others (1986). The hypothesis is simply explained as "if one area is subsiding while an opposing area is uplifted, a 'fulcrum' area in between is in dynamic equilibrium". In this hypothesis, fulcrum areas formed north-south trending depocenters of peat accumulation, which shifted across the Powder River Basin in response to prolonged episodes of uplift and subsidence along the west and east flanks of the basin. The coal-bearing sequences of the Tongue River Member tend to thicken to the west, suggesting that rates of subsidence increased from east to west during the Paleocene (Kent and others, 1986). At times when uplift or subsidence was relatively subdued, the fulcrum areas were broadest and clastic sedimentation into the basin was suppressed; this created conditions favorable to the accumulation of peat. Basin fulcrum areas shifted west during episodic uplift of the Black Hills along the eastern flank, at other times shifted east due to subsidence along the western flank. Several long-lived periods of subsidence and uplift, and corresponding fulcrum (peat accumulation) areas, have been recognized in the Tertiary strata of the basin. In late Tongue River Member time considerable volumes of sand were deposited in central parts of the basin, such as the Ashland Division area, which buried and preserved thick beds of peat; the rising

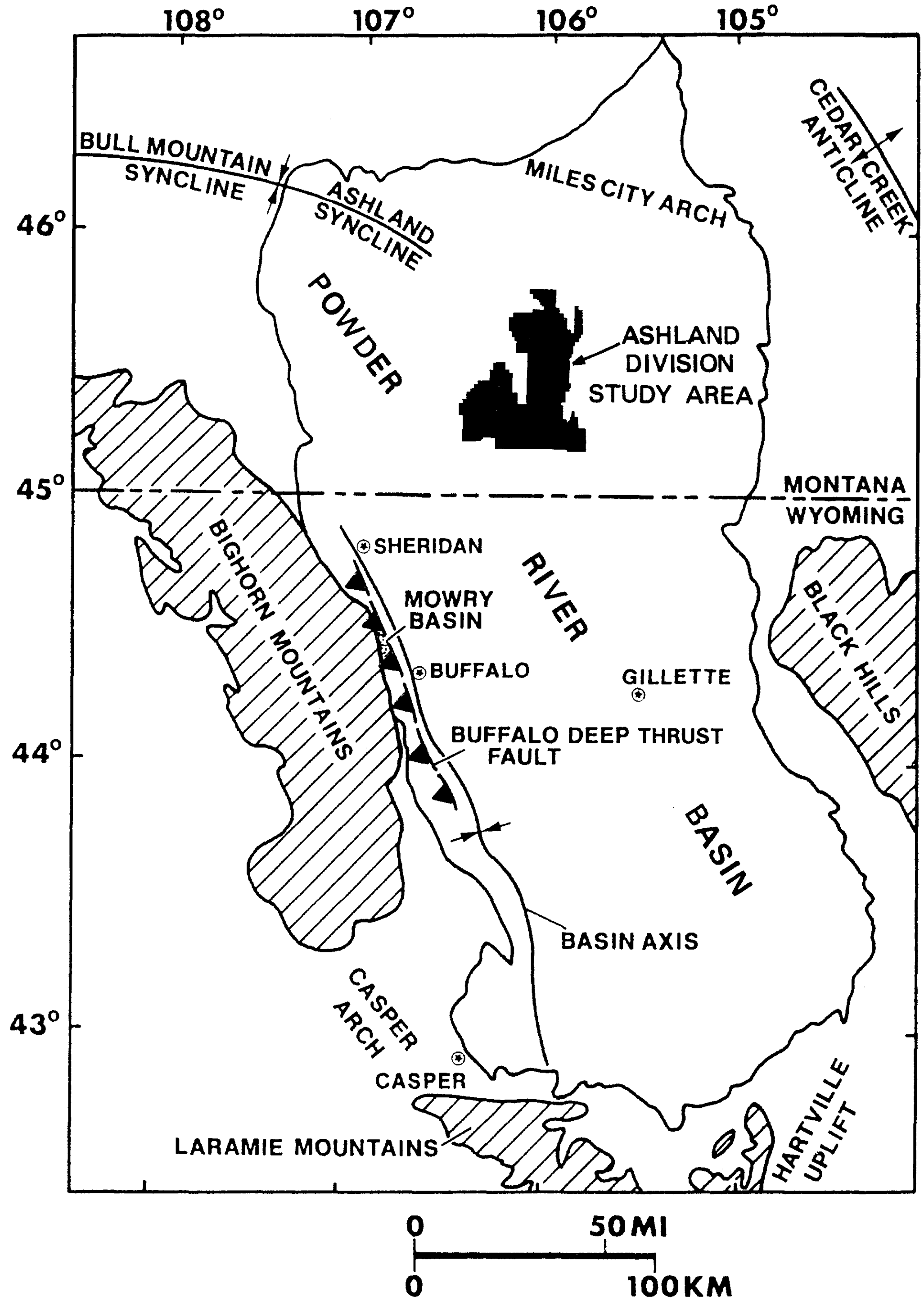

Figure 2. Index map showing major structural features of the Powder River Basin and location of the study area. Modified from Flores and Ethridge (1985).

Black Hills supplied the clastic material (McLellan and others, 1990). Thus, the architecture of the coal-bearing Tertiary sequences in the basin reflects the Laramide tectonic fluctuations of the region.

Due to the vast coal resources in the region, numerous geologic studies have been made on the northern Powder River Basin, including the Ashland Division area. Many of these investigations focused on the geologic conditions in which the thick peat deposits accumulated and were preserved during the Paleocene—the depositional environment. The thick Tongue River Member coal seams are recognized as the products of a dynamic fluvial system in the Powder River Basin during the Paleocene. The interpreted details of this depositional system, which allowed the development of thick swamp (peat) deposits, remain a matter of debate and some contention. Discussion of the contrasting models for the depositional environment of the Ashland Division coal deposits is beyond the scope and intent of this report. Instead, the reader is referred to the following papers for interpretations regarding the depositional environment of the Tongue River coals:

Ayers (1984, 1986a)
Ayers and Kaiser (1982, 1984)
Canavello (1980)
Flores (1981, 1983, 1986)
Flores, Belt and others (1982)
Flores and Ethridge (1985)
Flores, Toth, and Moore (1982)
Hanley and Flores (1987)
McLellan (1992)
Sholes and Cole (1981)
Sholes and Daniel (1992)
Yen (1948)

COAL GEOLOGY OF THE ASHLAND DIVISION AREA

The significant coal-bearing strata of the Ashland Division area occur within the Tongue River Member, which is the uppermost member of the Paleocene Fort Union Formation. The Tongue River Member is underlain by the Lebo Shale Member, which, in turn, is underlain by the Tullock Member (fig. 3). The Tongue River Member contains light-gray to light yellowish gray (weathers to buff or tan), very fine to medium-grained, thick-bedded to massive, calcareous sandstone and siltstone; medium-gray shaly mudstone, claystone and shale; brown to black carbonaceous shale; numerous coal beds, some as much as 80 ft (24 m) thick; thick red to lavender clinker and baked shale beds; and occasional thin beds of silty limestone. The Tongue River Member is up to 2,500 ft (760 m) thick and is distinguished from the underlying Lebo Shale Member by the predominance of siltstone and sandstone in the Tongue River compared to a predominance of shale in the Lebo Shale (Lewis and Roberts, 1978). The Lebo Shale Member consists mainly of dark shale with interbedded light-gray to black carbonaceous shale, siltstone, and local thin coal beds and sandstone; this member ranges from 0 to 600 ft (0 to 180 m) in thickness (Lewis and Roberts, 1978). The underlying Tullock Member consists mainly of gray thin-bedded sandstone and siltstone, light-gray shale, and local

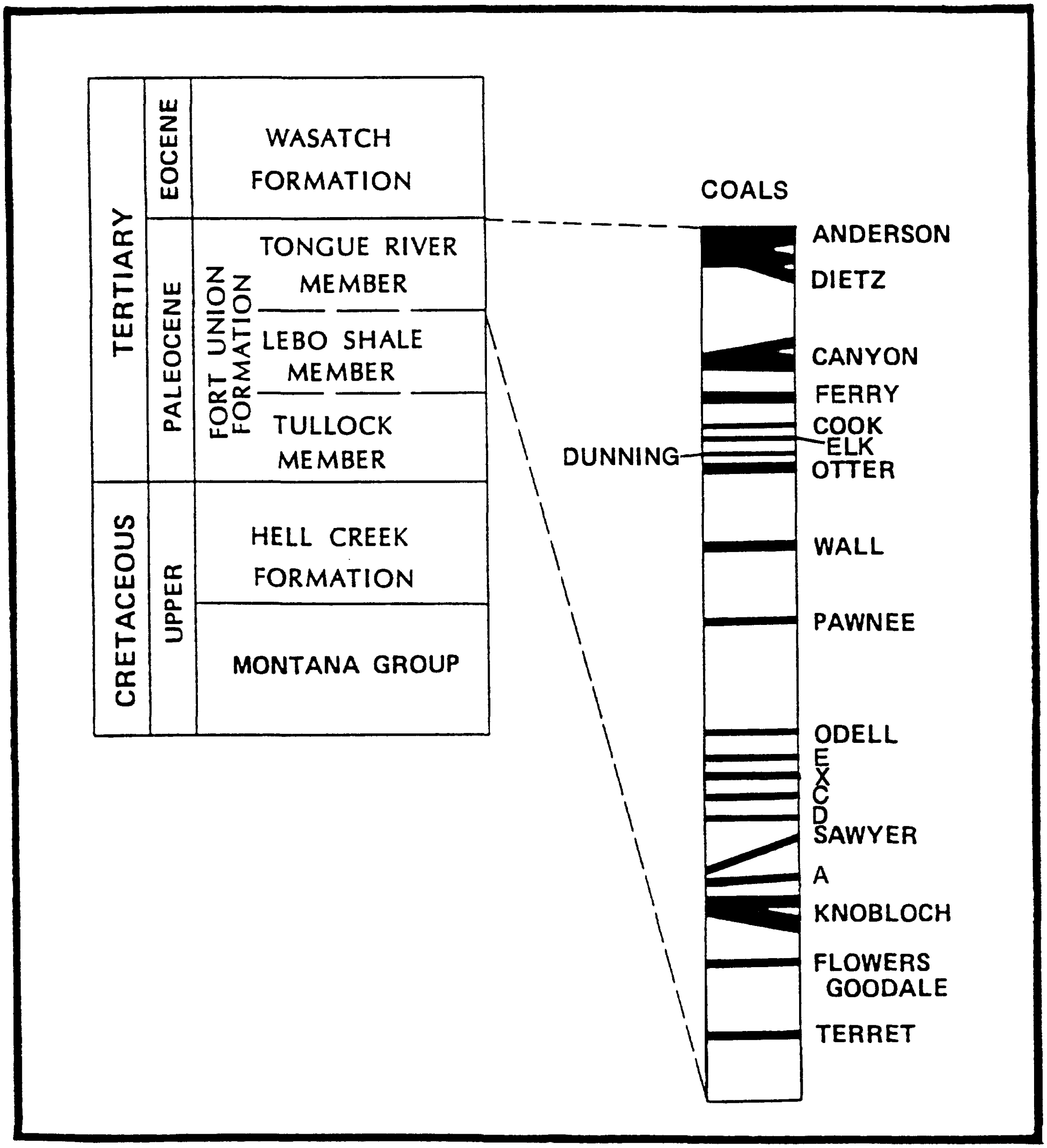

Figure 3. Generalized stratigraphic column (not to scale) for the northern part of the Powder River Basin region, including the Ashland Division study area. Modified from Sholes and Daniel (1992).

stringers of coal in the lower part which grade upward to gray carbonaceous shale. The Tullock Member ranges from 0 to 800 ft (0 to 240 m) in thickness in the area (Lewis and Roberts, 1978). Unconsolidated Quaternary channel deposits (alluvium) cover the Tongue River Member along the floors of stream valleys in the Ashland Division (plate 1).

The entire extent of the Ashland Division is underlain by coal beds of the Tongue River Member. About 20 coal beds have been correlated through the area within the upper 2,000 ft of strata (see Culbertson, 1987). Single coal beds within the study area exceed 65 ft in thickness (see Culbertson and Saperstone, 1987). The primary coal beds of the region are shown in figure 3. The Anderson-Dietz coal beds are the stratigraphically highest coals that occur within the Ashland Division study area. Locally, many splits (seams separated from the main seam by a thick parting of another sedimentary rock) occur for the coal beds shown in figure 3. Coal-bed nomenclature of the area has varied widely through time; however, it has become more consistent in the more recent publications (such as Culbertson, 1987; McLellan and Biewick, 1987, 1988, 1989; McLellan and others, 1990; Robinson and Culbertson, 1984; Derkey, 1986). References that display coal bed correlations across the Ashland Division are listed in table 1. Local, discontinuous coal beds, not shown in figure 3, are also common throughout the area. These beds are generally thin and not considered in the calculation of potential resources, but they present difficulties in correctly correlating coal beds between widely-spaced drill holes or outcrops. The correlation and stratigraphy of the Fort Union Formation coal beds across the Ashland Division area is probably best shown by Culbertson (1987), Derkey (1986), McLellan and Biewick (1988), and McLellan and others (1990).

Coal Quality

Analyses of 140 samples of coal from inside or near the Ashland Division indicate that the coals are relatively low in sulfur content, low to moderate in ash content, and range in apparent rank from lignite A to subbituminous B, based on the ASTM coal classification (American Society for Testing and Materials, 1991). Sulfur contents of the coals range from 0.087 percent up to 20.7 percent, with a high proportion of the coals (72.9 percent of the samples) containing less than 0.4 percent sulfur and most (94 percent) containing less than 1 percent sulfur. Ash contents range from 3.1 to 20.7 percent, but the majority of the coal samples show ash contents of 3 to 6 percent (72.9 percent of the samples).

Analyses of the same 140 coal samples from the Ashland Division area show heat of combustion values that range from 5,881 Btu per pound (Cook bed; Matson and Blumer, 1973, p. 104) to 9,662 Btu per pound (Canyon bed; Matson, 1971, p. 8). According to the ASTM specifications, moist mineral-matter-free coal ("as received") with heat of combustion values under 8,300 Btu (British thermal units) per pound is classified as lignite A; coal with heat of combustion values of 8,300 to 9,500 Btu per pound is classified as subbituminous C; and coal with heat of combustion values of 9,500 to 10,500 Btu per pound is classified as subbituminous B. A high proportion of the Ashland Division coal samples yield apparent ranks classified as lignite A (67.2 percent) or subbituminous C (31.4 percent), with a small representation of subbituminous B samples (1.4 percent). Publications that furnish coal quality (chemistry) data for Ashland Division coals are noted in table 1.

The general quality of the Ashland Division coals is typical of the coal in the Powder River region; that is, in comparison to other U.S. coals, "coals from the Powder River region

Table 1. List summarizing geologic references with coal geology information specific to part(s) of the Ashland Division study area. The treatment of the coal geology data varies widely amongst these publications, so this table outlines the primary types of information provided. Refer to section entitled "References Cited" for full reference citations of these papers.

Reference	Strippable coal[1]	Coal outcrops[2]	Coal zone isopachs[3]	Structure contours[4]	Coal zone correlations[5]	Coal chemistry[6]	Resource estimates[7]	Maps of clinker[8]
1) Affolter and others (1979)						■		
2) Bass (1932)	■	■					■	■
3) Bergantino and Cole (1981)	■					■	■	
4) Bergantino and others (1980)	■						■	
5) Biewick and McLellan (1990)		■	■		■			
6) Brown and others (1954)	■	■	■	■	■		■	■
7) Bryson and Bass (1973)		■			■		■	■
8) Cole and others (1982)	■							
9) Culbertson (1980)					■			
10) Culbertson (1981)					■			
11) Culbertson (1987)					■			
12) Culberston and Klett (1976)		■			■	■	■	■
13) Culbertson, Mapel and Klett (1976)		■			■	■	■	■
14) Culbertson and others (1980)					■	■		
15) Culbertson and Saperstone (1987)		■	■	■	■			
16) Derkey (1986)	■	■		■	■			■
17) Flores (1979)					■			
18) Flores, Toth and Moore (1982)					■			
19) Gilmour and Dahl (1967)						■		

Table 1. Continued.

Reference	Strippable coal[1]	Coal outcrops[2]	Coal zone isopachs[3]	Structure contours[4]	Coal zone correlations[5]	Coal chemistry[6]	Resource estimates[7]	Maps of clinker[8]
20) Heffern and others (1993)								■
21) Keefer and Schmidt (1973)	■							
22) Malde and Boyles (1976)	■							
23) Matson (1971)	■	■		■		■	■	■
24) Matson and Blumer (1973)	■	■	■	■	■	■	■	■
25) Matson and others (1968)	■	■	■	■	■	■	■	■
26) Matson and Pinchock (1977)						■	■	
27) McKay (1976a)		■					■	■
28) McKay (1976b)		■			■		■	■
29) McKay (1976c)		■			■	■	■	■
30) McLellan (1992)					■			
31) McLellan and Biewick (1987)		■						■
32) McLellan and Biewick (1988)					■			
33) McLellan and Biewick (1989)		■			■			■
34) McLellan and others (1990)					■			
35) Robinson and Culbertson (1984)	■	■	■	■	■			
36) Sholes and Daniel (1992)					■	■		
37) Trent (1986)							■	
38) U.S. Geological Survey (1974)	■							

Table 1. Continued.

Reference	Strippable coal[1]	Coal outcrops[2]	Coal zone isopachs[3]	Structure contours[4]	Coal zone correlations[5]	Coal chemistry[6]	Resource estimates[7]	Maps of clinker[8]
39) Warren (1959)							■	
40) Wegemann (1910)		■						

Explanation of footnotes:

[1] Contains map(s) showing areas where coal is potentially recoverable by surface mining methods. Strippable coal is generally defined as thick coal beds (>5 ft thick) overlain by no more than 500 ft of overburden, typically much less overburden. See each paper for their definition of "strippable coal".

[2] Contains map(s) showing the surface exposure(s) of coal beds.

[3] Contains map(s) showing isopachs (thickness contours) for subsurface coal beds or zones.

[4] Contains map(s) showing structure contours of coal beds or zones and (or) isopachs for the overburden.

[5] Contains diagram(s) showing the correlation of named coal beds or zones in part(s) of the Ashland Division, commonly extending the correlations to areas surrounding the National Forest.

[6] Provides chemical analyses of coal samples from the Ashland Division area. Analyses can include coal quality and (or) trace metals data.

[7] Provides coal reserve estimates for areas that include part(s) of the Ashland Division lands.

[8] Contains map(s) showing exposures of clinker (rock baked and deformed by the heat of a burning coal bed)

are characterized by relatively low ash, low sulfur, low heat of combustion, and high moisture content" (Affolter and others, 1979). Also, metals with potential environmental impact "such as As, Be, Hg, Mo, Sb, and Se are low in Powder River region coal when compared to most other U.S. coals" (Affolter and others, 1979).

Strippable Coal Deposits

At least one-third of the Ashland Division study area contains "strippable coal deposits" that are defined herein as one or more coal bed(s) greater than 5 ft thick overlain by less than 200 ft of overburden. Matson and Blumer (1973) show 16 strippable coal deposits that lie partially or wholly within Ashland Division lands. They provide overburden maps for each of the strippable coal deposits of the area. Maps showing the strippable coal in the Ashland Division area were also completed by Malde and Boyles (1976). The general outlines of the strippable deposits of the Ashland Division study area are shown on plate 2; the deposits are described briefly below from the northernmost deposit to the southernmost. Table 2 lists the coal beds that comprise the strippable deposits. The reader should refer primarily to Matson and Blumer (1973) for maps and data describing the specific characteristics of these coal deposits.

<u>Beaver Creek-Liscom Creek coal deposit.</u> This deposit is located within the northernmost part of the study area and contains strippable coal mainly in the Knobloch coal bed. In this deposit, the Knobloch bed, about 11-15 ft thick, crops out locally and occurs beneath less than 50 ft of overburden (Matson and Blumer, 1973, plate 29; Derkey, 1986; McLellan and others, 1990). Much lower tonnages of strippable coal occur within the Flowers-Goodale coal bed in the deposit (Matson and Blumer, 1973, plate 29).

<u>Foster Creek coal deposit.</u> Only a small part of this strippable coal deposit enters the Custer National Forest. The Knobloch coal bed, about 14 ft thick, lies beneath less than 90 ft of overburden along Bridge Creek (Matson and Blumer, 1973, plate 16A).

<u>Little Pumpkin Creek coal deposit.</u> This deposit consists of four local coal beds—from top to bottom, the E, X, C and D beds—and occurs in the northeastern part of the study area (Matson and Blumer, 1973, plate 27). The E, X, C, and D beds lie above the Sawyer bed (fig. 3). The E coal bed is about 7 ft thick (Bass, 1932), the X bed is about 8 ft thick, and the C and D beds appear at least 10 ft thick (Matson and Blumer, 1973).

<u>Ashland coal deposit.</u> This deposit, in the northwestern part of the study area, contains the largest tonnage of coal within the National Forest. Here, the Knobloch coal bed varies from 40 to 58 ft thick (Matson and Blumer, 1973, plate 13A; Derkey, 1986). Above the Knobloch coal bed, strippable coal is contained in, from top to bottom, the C and D, Sawyer and A coal beds. The C and D beds, with a combined thickness as much as 11 ft, crop out about 220 ft above the Sawyer bed (fig. 3; Matson and Blumer, 1973). The Sawyer coal bed ranges from 7-16 ft in thickness and lies about 80 ft above the A bed (Brown and others, 1954; Matson and Blumer, 1973, plate 13B; McKay, 1976c; McLellan and others, 1990). The A coal bed, about 9 ft thick, crops out within the study area about 85 ft above the Knobloch bed.

Table 2. List of the coal beds that comprise the strippable coal deposits within the Ashland Division of the Custer National Forest (plate 2). Strippable coal is defined herein as coal beds 5 ft or more in thickness overlain by less than 200 ft of overburden.

Coal deposit	Strippable coal beds
Beaver Creek-Liscom Creek	Knobloch
	Flowers-Goodale
Foster Creek	Knobloch
Little Pumpkin Creek	E
	X
	C
	D
Ashland	C
	D
	Sawyer
	A
	Knobloch
Home Creek Butte	Canyon
	Ferry
Threemile Buttes	Canyon
	Ferry
Sonnette	Cook
	Pawnee
Yager Butte	Cook
	Elk
	Dunning
Poker Jim Creek-O'Dell Creek	Knobloch
Otter Creek	Knobloch
Goodspeed Butte	Cook
Poker Jim Lookout	Anderson
	Dietz
Hanging Woman Creek	Anderson
	Dietz
Diamond Butte	Canyon
Fire Gulch	Cook
West Moorhead	Anderson
	Dietz
	Canyon

Home Creek Butte coal deposit. This coal deposit contains strippable resources in the Canyon and Ferry coal beds in the east-central part of the study area. In a Montana Bureau of Mines and Geology drill hole located within the National Forest, the Canyon bed was measured at 10 ft thick at a depth of 21 ft, lying 76 ft above the 24-ft thick Ferry bed (see Matson and Blumer, 1973, plate 26). The entire deposit lies within the study area; it is estimated to contain 217.21 million short tons of coal to a depth of 150 ft (Matson and Blumer, 1973).

Threemile Buttes coal deposit. This deposit lies in the east-central part of the Ashland Division study area and consists of strippable coal in the Canyon bed and underlying Ferry bed. The Canyon coal bed is comprised of two benches (splits) in the Threemile Buttes deposit with a maximum combined thickness of 17 ft (Matson and Blumer, 1973, plate 24; McLellan and Biewick, 1988). The Ferry coal bed outcrops in the northern part of the deposit, where it is up to 17 ft thick (Matson and Blumer, 1973, plate 24).

Sonnette coal deposit. Only a small portion of this coal deposit lies within the study area with strippable coals in the upper bench of the Cook bed and underlying Pawnee bed (Matson and Blumer, 1973, plates 25A and 25B). A drill hole located 2.7 miles east of the National Forest study area shows the upper Cook coal bed to be 10 ft thick, lying 193 ft above the 21-ft thick Pawnee coal bed (see Matson and Blumer, 1973, plate 25A). Another exploratory hole 2 miles to the north, drilled about 3 miles east of the Forest, showed that the Pawnee coal bed consists of two benches, 12 and 10 ft thick, separated by 4 ft of rock (see Matson and Blumer, 1973, plate 25A).

Yager Butte coal deposit. The Yager Butte coal deposit covers a large portion of the central region of the Ashland Division. This coal deposit contains strippable coal in the two benches of the Cook coal bed and underlying local coal beds named Elk and Dunning (lowest). In the southern part of the deposit within the National Forest, the benches of the Cook bed were measured in two Montana Bureau of Mines and Geology exploratory drill holes (see Matson and Blumer, 1973, plate 23B): the upper bench is 18 ft thick separated by 54-61 ft of rock from a lower bench of 11 ft in thickness. The Cook coal beds are thinner in the northern parts of this deposit within the National Forest (Matson and Blumer, 1973, plate 23B). In the study area, the Elk coal bed ranges from 10 to 21 ft thick and the underlying Dunning bed, which crops out locally, ranges from 12 to 20 ft thick (Matson and Blumer, 1973, plate 23A; Culbertson, 1980, 1987; McLellan and others, 1990). These beds are separated by 23-39 ft of rock (Matson and Blumer, 1973).

Poker Jim Creek-O'Dell Creek coal deposit. This coal deposit includes strippable coal in the western part of the Ashland Division in an area due south of the town of Ashland. The strippable coal occurs in thick seams of the Knobloch bed. Within the study area, the Poker Jim Creek-O'Dell Creek deposit can be divided into northern and southern strippable areas where thick benches of the Knobloch coal bed underlie less than 100 ft of cover. The northern area consists of the three largest parts of the Poker Jim-O'Dell Creek deposit shown in plate 2. Here, the Knobloch coal bed is 40-42 ft thick (Matson and Blumer, 1973, plate 11B; Derkey, 1986; Culbertson and Saperstone, 1987). In the southern portion of this northern area the Knobloch bed splits into three benches; the three benches form the strippable deposit in the southern part of the deposit. The upper and middle benches of the Knobloch coal bed in the southern area have a combined thickness of 27 ft (Matson and Blumer, 1973, plate 11A; Culbertson and Saperstone, 1987). The lower bench, 5 ft thick, rests 23 ft below the merged upper and middle benches (Matson and Blumer, 1973). The upper and middle benches of the Knobloch coal split in the westernmost part of the deposit within the study area (plate 2), where the upper bench is 7.5-9 ft thick, lying 29-32 ft above the 20-25 ft thick middle bench (Matson and Blumer, 1973, plate 11A).

Otter Creek coal deposit. The Otter Creek deposit, along the center of the Ashland Division area, contains considerable strippable coal within thick benches of the Knobloch coal bed. In an area along Threemile Creek (plate 1) and its tributaries, the upper bench of the Knobloch coal bed is about 61 ft thick and is covered by less than 100 ft of overburden (Matson and Blumer, 1973, plate 12). All benches of the Knobloch coal bed tend to thin and split south of Threemile Creek (Matson and others, 1968; Culbertson and Saperstone, 1987). Data from a drill hole near Tenmile Creek (plate 1) indicate that the upper bench is 20 ft thick separated by 87 ft of rock from the 12 ft thick lower bench (see Matson and Blumer, 1973, plate 12). Along Tenmile Creek in the study area, the upper bench of Knobloch coal is 20-22 ft thick (Matson and Blumer, 1973, plate 12; Culbertson and Saperstone, 1987). Nearby, on the west side of Otter Creek and within the study area, the upper bench is 22-25 ft thick (Matson and Blumer, 1973, plate 12; McKay, 1976b; Culbertson and Saperstone, 1987).

Two to six miles west of the Otter Creek coal deposit, the Lower Canyon bed crops out within rugged, steep topography in an area between O'Dell and Otter Creeks (plate 1). The Lower Canyon bed varies from 4 to 12 ft thick across this area (refer to McKay, 1976b; Robinson and Culbertson, 1984). The strippable coal potential throughout this area is low, because the lands with coal outcrops or thin overburden contain rugged topography not likely suited for strip mining methods.

Outcrops of the Lower Canyon coal bed occur in an area of steep terrain south of the Poker Jim Creek-O'Dell Creek coal deposit, located between the South Fork of Poker Jim Creek and O'Dell Creek. In this area the Lower Canyon coal bed is 6-12 ft thick (Robinson and Culbertson, 1984). The steep, rugged topography decreases the potential of the area for coal recovery with strip mining methods.

Goodspeed Butte coal deposit. This coal deposit lies entirely within the boundaries of the Custer National Forest. The strippable deposits consist of two benches of the Cook coal bed. In this coal deposit, Matson and Blumer (1973) estimated the strippable resources in the Cook coal bed to total 628.95 million short tons. Across this coal deposit, the widespread upper bench of the Cook bed ranges from about 13 to 20 ft thick and the lower bench ranges from 12 to 16 ft thick (Matson and Blumer, 1973, plate 20). The parting between these benches varies from 20-40 ft in thickness, appearing to thicken to the west and north across the deposit (Bryson and Bass, 1973; Matson and Blumer, 1973, plate 20; Culbertson, 1981).

Poker Jim Lookout coal deposit. This coal deposit, located in the southwest part of the study area, lies entirely within the Custer National Forest. Matson and Blumer (1973) estimated the strippable resources within the Anderson and Dietz coal beds in this deposit as 872.65 million short tons of coal. The Anderson and Dietz beds coalesce to form a single 58-ft-thick coal seam, under less than 100 ft of cover, in the area immediately surrounding Poker Jim Butte (see Matson and Blumer, 1973, plate 8).

Hanging Woman Creek coal deposit. Less than 3 miles south of the Poker Jim Butte coal deposit, the combined Anderson-Dietz bed splits into the Anderson and underlying Dietz. The Anderson coal bed varies from 30-34 ft in thickness in the northern part of the Hanging Woman Creek deposit (Matson and Blumer, 1973, plate 8; Culbertson and others, 1980). The Dietz coal bed is up to 25 ft thick near the area of split, thinning to 14 ft towards the southern part of the Hanging Woman Creek deposit (Matson and Blumer, 1973). As the Dietz coal bed thins, the parting between the Anderson and Dietz beds thickens from 17 ft near the area of split to 40 ft in the southern part of the deposit (Matson and Blumer, 1973, plate 8).

Where the Dietz coal bed crops out within the southwest corner of the study area (Matson and Blumer, 1973, plate 9; Bryson and Bass, 1973) it is about 14-20 ft thick (Matson and Blumer, 1973, plate 9). Thick, extensive outcrops of clinker are common in this area, formed by burning of the Anderson coal bed (Bryson and Bass, 1973; Culbertson and others, 1976). The Dietz coal bed is strippable in most of the clinker-rich area, here covered by less than 80 ft of clinker and other rock.

The Canyon coal bed crops out in rugged topography between the eastern edge of the Hanging Woman Creek coal deposit and Otter Creek (plate 1). In this area, the Canyon bed ranges from 24-30 ft thick (Bryson and Bass, 1973; Culbertson, 1980, 1987; Robinson and Culbertson, 1984). North of 45°15', the Canyon coal bed splits into two separate beds (Culbertson, 1980, 1987). The Lower Canyon coal forms the thicker seam north of the split line, ranging from 12 ft thick near the northeast part of the Hanging Woman Creek coal deposit to less than 4 ft thick near the southern end of the Otter Creek deposit (McKay, 1976a; Robinson and Culbertson, 1984). Outcrops of the Lower Canyon coal across this area occur on steep terrain west of Otter Creek (Robinson and Culbertson, 1984). The strippable potential for the Canyon coal bed(s) in this area is low due to the rugged terrain along the entire exposure of the Canyon coal bed.

In the southwestern corner of the Ashland Division study area, the Canyon coal bed outcrops in hillsides overlooking Lee Creek (Culbertson and others, 1976; Robinson and Culbertson, 1984). This area abuts the Hanging Woman Creek coal deposit, which lies to the east. The Canyon bed is as much as 32 ft thick near the head of Lee Creek within the study area (Culbertson and others, 1980; Robinson and Culbertson, 1984). Despite thick seams of the Canyon coal with thin overburden in the slopes above Lee Creek, the steep, rugged topography of these areas significantly lowers their suitability for strip mining.

Diamond Butte coal deposit. Most of this coal deposit lies within the Custer National Forest. Strippable coal occurs in the Canyon coal bed, which varies in thickness from 7 to 16 ft and tends to thicken from north to south across the deposit (Matson and Blumer, 1973, plate 19; Robinson and Culbertson, 1984; McLellan and Biewick, 1988, 1989). Also common to this coal deposit are outcrops of the Canyon coal bed and clinker formed by the burning of the Canyon bed (Bryson and Bass, 1973; Robinson and Culbertson, 1984; McLellan and Biewick, 1989).

Fire Gulch coal deposit. This deposit contains strippable coal in the southeastern part of the study area within the Cook coal bed. The Cook bed consists of two benches that outcrop along Bloom Creek, the north and south forks of the creek, and their upstream tributaries. Within the study area, the upper bench of the Cook coal bed is about 15 to 22 ft thick, separated from the lower bench by a 2-10 ft thick parting. The lower bench is 8-14 ft thick (Bryson and Bass, 1973; Matson and Blumer, 1973, plate 21).

West Moorhead coal deposit. The majority of this coal deposit lies south of the Ashland Division study area, however three coal beds contain strippable coal within the National Forest—the Anderson, Dietz, and Canyon coal beds. Within the study area, the Anderson coal bed was measured at 24 ft thick (Matson, 1971; Matson and Blumer, 1973, plate 10A; McLellan and Biewick, 1987, 1988). The Dietz coal bed, 5 to 11 ft thick south of the study area, is thinner or absent within the National Forest (Matson and Blumer, 1973; McLellan and Biewick, 1987). The Canyon coal bed ranges from about 18 to 26 ft in thickness within the study area (Matson, 1971; Matson and Blumer, 1973, plate 10C; Culbertson and others, 1980; Robinson and Culbertson, 1984). The Canyon bed outcrops in steep terrain between Bear Creek and Otter Creek (plate 1) along the southern boundary of the study area (Bryson and Bass, 1973; Robinson and Culbertson, 1984).

The Canyon coal bed is 16-18 ft thick in a small plateau area north of Indian Creek and south of Taylor Creek near the confluence of these creeks with Otter Creek (Bryson and Bass, 1973; Robinson and Culbertson, 1984). This coal deposit may not be considered a strippable deposit due to its small size, thus it is not shown on plate 2.

Estimated Resources of Non-Leased Federal Coal

The most comprehensive estimate of the non-leased federal coal resources of the Powder River Basin, including the lands of the Ashland Division area, was compiled by Trent (1986). As explained by Trent (1986):

> "The 1976 Federal Coal Leasing Amendments Act (P.L. 94-377) and the 1976 Federal Land Policy and Management Act (P.L. 94-579) require that a comprehensive inventory of unleased Federal coal be made available to the public. The U.S. Geological Survey (USGS) responded in fiscal year 1977 by initiating a Coal Resource Occurrence/Coal Development Potential (CRO/CDP) map program to 'determine the reserves of unleased Federal coal and to characterize for Federal land-use planning, the relative development potential of each leasable 40 acre tract' (Wayland, 1981, p. 543). The CRO/CDP map reports were to be compiled on 7.5-minute quadrangles using only publicly available data. Because of the need to meet time limitations of lease negotiations, most of the CRO/CDP work was to be done by consulting firms under contract; however, USGS geologists were to monitor each stage of completion."

Two hundred forty-three 7.5-minute quadrangle CRO/CDP reports cover the Powder River Basin. These were published as USGS Open-File reports, 28 of which cover the area of the Ashland Division (see table 3 for a list of the 28 USGS Open-File Reports). Methods used to calculate coal reserves are described in Trent (1986). The reserve base consists of Tertiary subbituminous coal beds 5 ft or more thick that occur at depths to 3,000 ft. Plate 3 shows the boundaries of the 7.5-minute quadrangles covered in the Ashland Division area and the reserve base of unleased federally owned coal within the approximate boundary of the National Forest.

The coal reserve estimates reported in the CRO/CDP reports (table 3, plate 3) suggest a

Table 3. List showing the CRO/CDP reports published as U.S. Geological Survey Open-File Reports that served as the basis for the estimated resources of non-leased federal coal within the Ashland Division study area (plate 3). The 28 Open-File Reports listed below correspond to the Ashland Division area of the present study. The right most column shown below lists additional U.S. Geological Survey reports that provide separate coal resource estimates specific to the corresponding quadrangle area. Full citations for all of these reports are provided in the section entitled "References Cited".

7½-minute quadrangle	U.S.G.S. Open-File Report	Additional U.S.G.S. report, Author(s)
Ashland	C.S.M.R.I.[1] (1979a)	Malde and Boyles (1976)
Beaver Creek School	C.S.M.R.I.[1] (1980a)	no other report specific to this quadrangle
Birney Day School	C.S.M.R.I.[1] (1980b)	Malde and Boyles (1976)
Bloom Creek	C.S.M.R.I.[1] (1980c)	McLellan and Biewick (1989)
Browns Mountain	Mapel and Martin (1978)	Culbertson and Klett (1976)
Coleman Draw	C.S.M.R.I.[1] (1980d)	Malde and Boyles (1976)
Cook Creek Reservoir	C.S.M.R.I.[1] (1979b)	no other report specific to this quadrangle
Elk Ridge	C.S.M.R.I.[1] (1979c)	no other report specific to this quadrangle
Fort Howes	McKay and Robinson (1979a)	McKay (1976a)
Goodspeed Butte	C.S.M.R.I.[1] (1980e)	Malde and Boyles (1976)
Green Creek	C.S.M.R.I.[1] (1980f)	Malde and Boyles (1976)
Hamilton Draw	Mapel and others (1979a)	Malde and Boyles (1976)
Hayes Point	C.S.M.R.I.[1] (1979d)	no other report specific to this quadrangle
Hodsdon Flats	C.S.M.R.I.[1] (1980g)	Malde and Boyles (1976)
Home Creek Butte	C.S.M.R.I.[1] (1980h)	Malde and Boyles (1976)
King Mountain	C.S.M.R.I.[1] (1980i)	McKay (1976b)
North Stacey School	C.S.M.R.I.[1] (1979e)	no other report specific to this quadrangle
Otter	McKay and Robinson (1979b)	Malde and Boyles (1976)
Phillips Butte	C.S.M.R.I.[1] (1980j)	Malde and Boyles (1976)
Poker Jim Butte	Mapel and others (1979b)	Malde and Boyles (1976)
Reanus Cone	C.S.M.R.I.[1] (1980k)	Malde and Boyles (1976)
Samuelson Ranch	C.S.M.R.I.[1] (1980l)	Malde and Boyles (1976)
Sayle	C.S.M.R.I.[1] (1980m)	McLellan and Biewick (1987)
Stacey	C.S.M.R.I.[1] (1979f)	no other report specific to this quadrangle
Stroud Creek	Mapel and others (1978)	Culbertson and others (1976)
Threemile Buttes	C.S.M.R.I.[1] (1980n)	Malde and Boyles (1976)
Willow Crossing	C.S.M.R.I.[1] (1980o)	McKay (1976c)
Yager Butte	C.S.M.R.I.[1] (1980p)	Malde and Boyles (1976)

[1]"C.S.M.R.I." = Colorado School of Mines Research Institute

total of 42.28 billion short tons of non-leased federal coal inside the Ashland Division area (to a depth of 3,000 ft). These reports indicate that the largest coal resources in the study area occur in the area of the Poker Jim Butte 7.5-minute quadrangle (plate 3), estimated to contain 3.740 billion short tons of coal, calculated to a depth of 1,000 ft. This area includes much of the northern part of the Hanging Woman Creek coal deposit and all but a small western edge of the Poker Jim Lookout coal deposit.

CLINKER

One of most abundant resources of the Ashland Division lands, aside from coal, is plentiful outcrops of clinker. Clinker is a brittle, resistant, brick-like, usually reddish rock that formed by the heat produced from the burning of an underlying coal bed. The jagged, fused and melted textures in the baked rock—clinker—often resembles the appearance of slag from a furnace. Clinker formed by burning coals are occasionally called "scoria" or "natural coke".

Natural processes have ignited coals that resulted in extensive masses of clinker throughout many parts of the northern Powder River Basin region, as shown by Heffern and others (1993). Clinker is an important resource within the region. It is crushed and used locally for surfacing improved unpaved roads and as an aggregate material in paved roads. The abundance, accessibility, ease of excavating, and proximity of the clinker to the roads where it is needed has lead to widespread use across the basin. Clinker outcrops are especially abundant within the Ashland Division lands, locally reaching more than 100 ft in thickness. For example, thick masses of reddish and multicolored clinker, formed by the burning of the Knobloch coal bed, are found along the East Fork of Otter Creek and its tributaries. Several maps have been published that outline exposures of clinker for various parts of the Ashland Division (for example, see Bryson and Bass, 1973; Matson and Blumer, 1973; Culbertson and Klett, 1976; Culbertson, Mapel and Klett, 1976; McLellan and Biewick, 1987, 1989; McKay, 1976a-c). Clinker occurrences for the entire northern Powder River Basin, including the Ashland Division study area, are shown by Heffern and others (1993).

Potential mining of clinker outcrops in the Ashland Division area would depend primarily on local need, accessibility, and proximity to roadways requiring clinker. Such an appraisal on a local basis is beyond the scope of this study.

POTENTIAL FOR OIL AND GAS RESOURCES

The Powder River Basin is a prominent petroleum province of the United States, being one of the largest producing areas in the Rocky Mountain region. Structural and stratigraphic traps in the basin are known to hold more than 2.5 billion barrels of recoverable oil (Dolton and others, 1990), found in strata ranging from late Paleozoic to Late Cretaceous in age (fig. 4). Despite the abundance of oil reservoirs in the basin, relatively small quantities of gas resources have been identified. However, recent assessments suggest that the potential for natural gas resources in the basin may have been previously underestimated (Gautier and others, 1995; U.S. Geological Survey, 1995).

Even though the Powder River Basin as a whole possesses considerable petroleum resources, the area comprising the Ashland Division has no past or present history of oil or gas

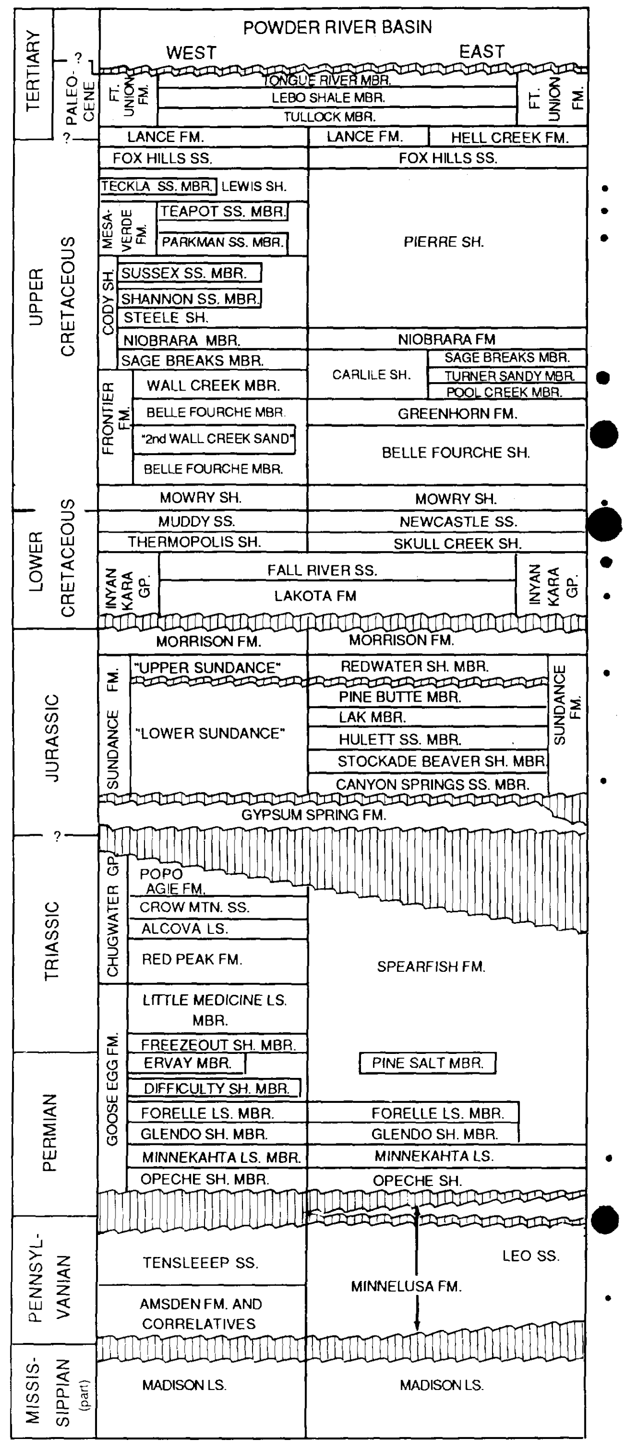

Figure 4. Stratigraphic column of the Powder River Basin; diagram was reproduced with permission from Fox and others (1991). The main petroleum producing horizons are shown as black dots with the size of the dots indicating relative volume of oil.

production. The producing fields closest to the Ashland Division study area are: (1) the Pumpkin Creek gas field, centered about 10 miles to the northeast of the study area; (2) the Liscom Creek gas field, centered about 6 miles to the north-northwest of the study area; (3) the Leary oil field, centered about 19 miles to the southeast of the study area; (4) the Wright Creek oil field, centered about 28 miles to the east-southeast of study area; (5) and the Bell Creek oil field, centered about 35 miles to the southeast of the study area (Bergantino and others, 1980; Bergantino and Cole, 1981; Board of Oil and Gas Conservation, 1992). A modest amount of oil and gas exploration has occurred within the Ashland Division study area, but no productive reservoirs have been discovered. Sites of oil and gas test wells are shown in Balster (1973); Biewick and McLellan (1990); Culbertson (1987); Culbertson and Klett (1976); Culbertson, Mapel and Klett (1976); Denson and Crysdale (1991); Derkey (1986); Matson (1971); Matson and Blumer (1973); McKay (1976a, 1976b); and McLellan and others (1990).

Prospective petroleum "plays" in the Powder River Basin were described and delineated by Dolton and others (1990). Such plays serve as the foundation for oil and gas assessment. They depict the primary stratigraphic and structural occurrences of known petroleum reservoirs throughout the basin and allow projection to the other subsurface regions with similar geologic attributes. Dolton and others (1990) identified the following five petroleum plays that lie within the Ashland Division area:

1. **Lakota play**. This play includes oil in sandstones within the Lakota Formation of the Lower Cretaceous Inyan Kara Group (fig. 4). Structural traps at this horizon are deemed insignificant; the primary reservoirs are thought to exist in stratigraphic traps formed by "discrete or composite channel sandstones of alluvial or deltaic origin sealed by fine-grained alluvial deposits" (Dolton and others, 1990).

2. **Fall River ("Dakota") Sandstone play**. This play involves oil and gas occurrences found within stratigraphic traps in a Lower Cretaceous "regressive clastic wedge of the Fall River Formation" (upper Inyan Kara Group, fig. 4) (Dolton and others, 1990).

3. **Muddy-Newcastle play**. This play comprises stratigraphic traps holding oil and gas in the Muddy-Newcastle Sandstone complex (fig. 4) of Lower Cretaceous age. "Reservoirs include marine bar and strandline, channel, estuarine, alluvial and lower delta plain sandstone bodies" (Dolton and others, 1990).

4. **Mowry Shale play**. Oil and gas pools occur in fractured Mowry Shale (Lower Cretaceous, fig. 4) in deeper regions of the Powder River Basin. The source of the fracturing is still debated, but the "highly organic Mowry Shale is considered both reservoir and source" for the petroleum (Dolton and others, 1990).

5. **Shannon Marine Shelf Sandstone play**. Petroleum accumulations in stratigraphic traps occur within the Shannon Sandstone Member of the Cody Shale (Upper Cretaceous, fig. 4); these are found in deep parts of the basin. The reservoir sandstones are thought to represent offshore sand deposition on a broad and shallow progradational marine shelf.

The five petroleum plays of Dolton and others (1990) that extend into the Ashland Division area remain hypothetical, because no oil or gas reserves have been discovered as yet beneath this area. Refer to Dolton and others (1990) for more thorough descriptions of these plays and for maps that show their extent. It is noteworthy that the Ashland Division area appears to lack the prominent structural features typically associated with the accumulation of oil and gas, such as anticlines and domes. The general attitude of the exposed strata suggest a regional dip of ½° southwestward toward the basin axis. The scattered local structural perturbations in the strata lack the characteristics of favorable structural oil and gas traps.

POTENTIAL FOR COAL-BED METHANE RESOURCES

Coal-bed methane gas has not been exploited in the Ashland Division study area. Yet, undiscovered coal-bed methane resources may exist there. Choate and others (1984) evaluated the coal-bed methane resource of the Powder River Basin and reached the following conclusions:

> "Powder River Basin of Wyoming and Montana presents an unusually promising opportunity for collecting large amounts of methane gas from relatively shallow coalbeds. The basin is very large and contains the largest concentration of thick coalbeds in the nation. Though the coals are of low rank, which normally indicates small amounts of adsorbed methane per unit volume of coal, the great thickness of many of the coal seams indicates large volumes of methane contained per unit area of land surface......Because of the high porosity of these low-rank coals and the great total thickness of coal encountered at shallow depths, large amounts of methane should be recoverable per unit length of drill hole."

Choate and others (1984) delineated a "prime methane exploration target area" for the northern Powder River Basin that included the southernmost parts of the Ashland Division. They note the gas desorption results for core samples of coal beds collected from a drill hole completed 3 miles south of the Ashland Division. Gas was measured from 3 samples each of the Anderson and Canyon coal beds; each bed yielded average gas contents of 2 cubic ft of gas per ton of coal. The sampled Anderson coal bed was 52.6 ft thick and the depth to the top of the bed was 243 ft; the sampled Canyon coal bed was 24.5 ft thick and the depth to the top of the bed was 337 ft. Gas desorption analyses of coal samples from 10 wells in the basin in Wyoming and Montana yielded predictable results; that is, methane gas contents were generally highest within the thicker, deeper coal seams. For example, methane gas content reached 71 cubic ft per ton of coal for a 48 ft thick coal bed at a depth of 1,235 ft. Thus, the methane gas resources of the Ashland Division are potentially greatest where the thickest coal bed of the study area—the Knobloch coal—occurs at the greatest depth. Such an area, for example, may occur in sections 19 and 20 of T. 4 N., R. 46 E., where the Knobloch coal is 60-65 ft thick and buried beneath about 500 ft of overburden (Culbertson and Saperstone, 1987). The Knobloch bed is more deeply buried in the southwestern part of the Ashland Division study area, lying at more than 1,000 ft of depth; however, the Knobloch coal seam splits and thins to 10-20 ft thick (Culberston and Saperstone, 1987).

The 1995 National Assessment of United States Oil and Gas Resources (Gautier and others, 1995; U.S. Geological Survey, 1995) did not include the Ashland Division area within their coal-bed gas play for the Powder River Basin. Their play ("target area") included areas in the basin where Fort Union coal beds are deeper than 500 ft. Based on this criteria, the Ashland Division study area could be included in this play. However, Rice and Finn (1995) assess the potential for coal-bed gas reserves from the Powder River Basin play as fair to poor. They note "sparse data indicate that the gas contents, because of low rank, may not be significantly higher with increasing depth". Also, "the coals may be undersaturated with respect to gas, and large amounts of groundwater are present in the cleat systems". Commercial coal-bed gas production has not been proven in the Ashland Division area. The potential for this resource remains largely untested in the National Forest.

CONCLUSIONS

The resource wealth of the Ashland Division area exists in enormous, world-class reserves of low sulfur lignite and subbituminous coal. Roughly one-third of the Ashland Division contains strippable coal (coal bed(s) more than 5 ft thick overlain by less than 200 ft of overburden) within 17 coal deposits (plate 2). By one estimate (table 3, plate 3), about 42 billion short tons of non-leased federally owned coal remain in the Ashland Division (to a depth of 3,000 ft). At least 20 coal beds have been correlated through the area within the upper 2,000 ft of strata, which consists entirely of the Paleocene Tongue River Member of the Fort Union Formation. Individual coal beds are up to 65 ft in thickness within the National Forest.

Many areas in the Ashland Division appear especially favorable for strippable coal deposits, where thick coal seams are covered by thin overburden. Particularly noteworthy areas include these coal deposits:

1. In northern and western parts of T. 1 S., R. 46 E. within the National Forest, the Knobloch coal bed is only 11-15 ft thick; however, it rests beneath less than 50 ft overburden in much of this area (see Matson and Blumer, 1973, plate 29).
2. The Ashland coal deposit contains the largest tonnages of coal resources within the National Forest (see Matson and Blumer, 1973, plates 13A and 13B). The Knobloch coal bed is 40-58 ft thick, overlain by less than 150 ft of overburden, in: (i) the west side and southeast corner of T. 2 S., R. 45 E.; (ii) all of T. 3 S., R. 45 E., in the Forest; (iii) western parts of T. 3 S., R. 46 E.; and (iv) the southwest corner of T. 2 S., R. 46 E. Strippable coal also occurs in other portions of this deposit within the Sawyer coal bed. In several areas, the Sawyer bed, 7-16 ft thick, lies within 50 ft of the surface.
3. In the Yager Butte coal deposit the Dunning bed is 12-20 ft thick, but overlain by less than 50 ft of overburden in: (i) the southern half of T. 3 S., R. 46 E.; (ii) southwestern parts of T. 4 S., R. 47 E.; (iii) northwestern parts of T. 5 S., R. 47 E.; and (iv) most of T. 5 S., R. 46 E. (see Matson and Blumer, 1973, plate 23A).
4. The Knobloch coal bed is 40-42 thick, lying under less than 100 ft of cover, within parts of sections 10, 15, 21 and 28 of T. 4 S., R. 44 E. (see Matson and Blumer, 1973, plate 11B).
5. The upper bench of the Knobloch bed thickens to 61 ft near Threemile Creek, covered by less than 100 ft of overburden in sections 5, 6 and 7 of T. 4 S., R. 46 E. (see

Matson and Blumer, 1973, plate 12).

6. In the area immediately surrounding Poker Jim Butte, in the northwestern part of T. 6 S., R. 44 E., the merged Anderson-Dietz coal seam reaches 58 ft in thickness and in places lies beneath less than 50 ft of overburden. To the south and east of Poker Jim Butte, the Anderson-Dietz splits into the respective beds—the Anderson bed and the Dietz bed. The Anderson bed varies from 30-34 ft in thickness and the Dietz bed reaches up to 25 ft of thickness across the area between Poker Jim Butte, southward to the North Fork of Lee Creek. In many parts of this area, referred to as the Poker Jim Lookout coal deposit (see Matson and Blumer, 1973, plate 8), the Anderson and Dietz coals appear favorable for stripping, each coal bed often found under less than 50 ft of overburden.
7. In the southwestern part of the Ashland Division, along the southern boundary of the National Forest, the Dietz coal is 14-20 ft thick and in areas covered by less than 80 ft of clinker and other rock (see Matson and Blumer, 1973, plate 9; Culbertson, Mapel and Klett, 1976).
8. Along the North and South Forks of Bloom Creek, in the southeastern part of the study area, strippable reserves occur in the Cook bed. In this area the upper bench of the Cook coal is about 15-22 ft thick, separated by 2-10 ft of rock from the lower bench, which is 8-14 ft thick (see Matson and Blumer, 1973, plate 21).

The other abundant resource of the Ashland Division lands, aside from coal, is expansive thick outcrops of reddish clinker. These rocks were baked, fused, and melted by the natural burning of underlying coal beds. Within the Powder River Basin region, clinker is crushed and used locally for surfacing improved unpaved roads and as an aggregate material in paved roads. Clinker has widespread use in the basin because of its abundance, accessibility, ease of excavating, and proximity to the roads where it is used.

The Ashland Division area has no past or present history of oil and gas production. The Powder River Basin as a whole is a major petroleum province and one of the largest producing areas in the Rocky Mountain region. However, despite a modest amount of oil and gas exploration in the Ashland Division, no productive reservoirs have been discovered within the National Forest. Dolton and others (1990) describe five prospective petroleum plays that include the Ashland Division area. These plays involve possible stratigraphic and structural traps in specific Lower and Upper Cretaceous strata that host producing horizons elsewhere in the basin. These plays remain hypothetical for the Ashland Division area, because no oil or gas resources have been proven beneath the Forest. The Ashland Division area appears to lack the structural features typical of oil and gas accumulation, such as prominent anticlines and domes.

The potential exists for undiscovered coal-bed methane gas resources within the Ashland Division. This resource has yet to be developed or proven within the National Forest. A "prime methane exploration target area" was drawn by Choate and others (1984) for the northern Powder River basin, which included southernmost parts of the Ashland Division lands. In contrast, the 1995 National Assessment of United States Oil and Gas Resources (Gautier and others, 1995; U.S. Geological Survey, 1995) defined a coal-bed gas play for the basin that did **not** include the Ashland Division area. Areas where Fort Union Formation coal beds lie deeper than 500 ft should have potential for coal-bed methane. Many areas of the Ashland Division meet this criteria. Commercial coal-bed gas production is unproven in the study area, however the potential for this resource remains mostly untested inside the National Forest.

Neither the geology nor the results of geochemical surveys suggest any potential for metallic mineral deposits within the Ashland Division of the Custer National Forest.

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