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Coal in Montana

Clifford A. Barkell

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COAL IN MONTANA

by

CLIFFORD A. BARKELL

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

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Butte, Montana
April 26, 1943
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INTRODUCTION

Coal was first mined in Montana in the year 1880. For the last thirty years the mining of coal in this state has been very important with few people realizing its value. In the mineral industry, the value of the annual production of coal is exceeded by none of the non-metallics, and only by gold, silver, and copper in the metallics. At the present time the coal production of Montana is valued at about $4,000,000.00 annually.

Central and eastern Montana have enormous coal reserves, few of which have been exploited to a great extent. Until the event of natural gas, coal was the chief fuel used in the state, and most of the markets are within the borders of Montana.

Nearly all of the known coal deposits of Montana have been examined by competent geologists, and many technical reports of their findings have been published, mostly in the various bulletins of the United States Geological Survey. The purpose of this report is to give general descriptions of the many coal fields and the general geology of the coal-bearing strata so that persons interested in the industry may have a better knowledge of the coal resources of the state.

All of the coal-bearing strata of Montana occur in Tertiary and Cretaceous formations. The principal coal producing formations are the Fort Union group and the Lance in central and eastern Montana, the Judith River and Eagle
in the central part of the state, and the Kootenai formation in the north-central part of Montana.

The coals of Montana are bituminous, subbituminous, and lignite with the chief production being of the subbituminous grade. A small amount of coking coal is in the south-central part of the state, but it is not mined to much extent at present.

Some of the diagrams used in this report have been redesigned from other maps and diagrams obtained from various sources. Authority for these figures has been given either on the diagrams themselves or in the text of the report.

The author wishes to thank Dr. Eugene S. Perry, Professor of Geology at Montana School of Mines, under whose supervision this work was undertaken. His suggestions and ideas have proved invaluable in the making up of this report.

GENERAL GEOLOGY

Geologic History

The geologic history of the pre-Cambrian and Paleozoic sediments of Montana has practically no bearing on the occurrence of coal. At the close of the Paleozoic era Montana was a land mass and persisted as such until the middle part of Jurassic time. This land mass was not mountainous, and erosion cut into the existing relatively horizontal sediments. In the northern part of the state the Madison limestone was exposed, and most of the erosion on this formation was of a chemical nature and in places left the limestone cavernous in
which oil later accumulated.

In the middle and late parts of the Jurassic period a sea spread throughout most of the state, as a result of which limestones, shales, and impure sandstones of the Ellis formation were deposited. This sea was rather shallow, and of the mediterranean type. On top of the Ellis formation in the southern part of the state terrestrial deposits of the Morrison formation accumulated, and these are thought to be of Jurassic age or else transitional between the Jurassic and Lower Cretaceous periods.

At the end of the Jurassic period Montana was again a land mass, and remained as such through most or all of the Lower Cretaceous. Part of the land must have been low-lying with extensive swamps, because coal is found in the Kootenai formation of Lower Cretaceous age which is present throughout most of Montana. The name Kootenai is applied to Lower Cretaceous deposits (200 to more than 1500 feet thick) in the northern and central part of the state, and Cloverly formation is the name applied south of Billings. Perry explains Lower Cretaceous deposition in Montana as follows: "Apparently these deposits are of a piedmont type; material laid down on a broad nearly level plain in front of a mountainous area by many rivers which flowed across the plain. In Montana the rivers must have had an easterly trend. It is known that about this time a high and probably

*Perry, E.S.; Natural Gas in Montana; Montana Bureau of Mines and Geology, Memoir No. 3, p. 5, 1937.*
mountainous land mass, the northern extension of the Sierra Nevada Range, existed west of Montana, and that an inland sea extended from the Gulf of Mexico northward into Wyoming. During this time swampy conditions existed in parts of Montana and coal was formed."

At the beginning of Upper Cretaceous time 2000 or more feet of shaly sediments were deposited in a sea which covered all of central and eastern Montana and extended from the Gulf of Mexico to the Arctic Ocean. This group of sediments has been given the name of the Colorado group. The latter part of the Upper Cretaceous period was a time when the Montana group of sediments was deposited. Westward advances and eastern recessions of the shore line of a continuation of the Colorado sea caused a unique situation, with the sandy Eagle and Judith River formations laid down during retreats, and Claggett and Bearpaw marine shales during advances. The shore line migrated from east to west in the state. Interestingly, sediments were deposited regardless of whether or not the sea covered the area. Because of this, the Eagle and Judith River formations are terrestrial in the central part of the state and have marine equivalents in the eastern part.

The close of the Cretaceous period and beginning of the Tertiary period are marked by the uplift of the Rocky Mountains in the western part of the state. It is believed that the Lance, Fort Union, and Wasatch formations of Tertiary time are the results of deposition of erosion
products of the Rocky Mountains. The laccolithic mountains of central Montana probably rose after the deposition of the Fort Union group and Wasatch, because these sediments are often folded near the mountainous areas. Terrace gravel of middle Tertiary time often covers these folds indicating that the uplifts occurred before the gravel was deposited and after the underlying lower Tertiary formations were laid down.

The streams of northern Montana during late Tertiary time flowed northward to the Arctic Ocean at levels much higher than at present. It was sometime during the Pleistocene epoch that these rivers were turned to the south by the advance of the great ice sheets from Canada, and developed their present valleys.

Stratigraphy

About the only parts of Montana in which no coal deposits of importance occur are the western mountainous regions, and the smaller mountainous portions in the central part of the state. Of the plains area of Montana, Perry estimates that possibly 98 percent of the exposed strata are of Tertiary and Cretaceous age, and these strata collectively have an average thickness of about 6500 feet.

In a report of this nature it would be impossible to discuss a series of strata which would be applicable to the entire region, as local variations in the stratigraphy

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*Perry, E. S.; Natural Gas in Montana; Montana Bureau of Mines and Geology, Memoir No. 3, p. 6, 1937.*
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are very common. In general, a discussion of each formation giving its lithologic characteristics and other important features will be made. In the descriptions of the individual fields and areas, lithologic features of the formations will not be mentioned except in rare instances when some feature is peculiar to one particular region. Quite often, a formation will have several names applied to it, a different one in each region, and in some places members of formations may be so prominent that they will be referred to as formations instead of members. To aid the reader a correlation chart of formations in Wyoming, Montana, and the Dakotas is included in this report.

All commercial coal occurrences are found in strata of Cretaceous and Tertiary age, so little will be said about Paleozoic and Lower Mesozoic formations.

Wasatch Formation. The Wasatch formation is Miocene in age. Stratigraphically it lies above the Fort Union group, and it is found in the south-central portion of Montana. Lithologically the Wasatch is similar to the Fort Union group. The formation is of minor importance in its relationship to the coal industry of Montana.

Fort Union Group. The Fort Union formation or group of formations is one of the most prominent groups in central and eastern Montana, and is a large producer of coal. It was named for an old military post at the mouth of the Yellowstone River. Usually it is considered as Tertiary,
although it is really transitional between the Cretaceous and Tertiary periods. However, the reasons for considering it as Tertiary are found in the character of the plant and animal remains which are characteristic of the Cenozoic era. Formerly, the Fort Union group was considered as a single formation and in this report will often be referred to as such. Geologists at the present time, however, consider it to be a group composed of two formations, the Tongue River above and the Lebo shale below, which were previously called members.

The Tongue River formation commonly is composed of somber-colored shales and coarse yellow sandstones interbedded with carbonaceous sandstone and shale. In some localities it has a dark gray color and contains brown feruginous and sandy nodules and concretions.

The Lebo formation typically is composed of thick beds of dark shale alternating with thick beds of white sandy clay. Commonly lenticular masses or beds of sandstone are present in the formation. This formation changes in character from place to place and in the northeastern part of the state usually consists of some somber-colored sands and clays with numerous carbonaceous layers. Coal beds are scattered throughout the formation in most localities. In the Bull Mountain coal field, for example, there are several beds of such a thickness as to be considered mineable. Commonly the Fort Union group has a thickness of about 1000 to 2000 feet, but in places as much as 4300 feet have been measured.
Lance Formation. Stratigraphically below the Fort Union group is the so-called Lance formation. The term "Lance" has been used so much as a formation name in the past it is necessary to consider it in any report on Montana coal. Formerly it was the name given to a single formation composed of two members, which are now considered to be separate and true formations. It was thought to be Upper Cretaceous in age. However, there is a tendency at present to abandon the name Lance, and to use the names of its divisions. Also, at the present time, the tendency is to include the upper formation in the Tertiary and the lower in the Cretaceous, although it is not easy to definitely separate the Tertiary and Cretaceous in Montana. Observers who are not familiar with the Fort Union and Lance formations may have trouble distinguishing between them in the field, and it is nearly impossible to tell hand specimens of the two apart.

The upper formation of the Lance has been named the Tullock, and is usually a series of alternating beds of somber light and dark shale along with sandy shale and sandstone. Commonly it has a yellowish color and resembles the Tongue River formation of the Fort Union group. In the southeastern corner of the state, the upper member of the Lance is known as the Ludlow lignitic formation and has been described as a yellowish to gray sandstone along with beds of shale and lignite.
The lower formation of the Lance has been given the name of Hell Creek. It is made up chiefly of somber shale with one or more beds of buff-colored sandstones in the lower part.

In the north-central part of Montana two formations, the Willow River and the St. Mary River, are equivalent to the Lance. The St. Mary River formation has several beds of coal in it in Glacier and Pondera counties.

The Fort Union and Lance formations together supply the majority of Montana coal and lignite although the Judith River and Kootenai formations are important.

Fox Hills Formation. At the base of the Lance formation is a massive sandstone 50 to 150 feet thick which is known as the Fox Hills formation. It is quite persistent and can usually be recognized throughout most of Montana. Lithologically, it is very similar to the Lance and is considered by some geologists as a basal member of the Hell Creek. Perhaps more properly it should be considered as the topmost formation of the Montana Group. South of Glendive a group of beds of indurated sandstones and somber and yellow clays and shales lies at the base of the Hell Creek formation and is given the name Colgate sandstone. In all probability, this is the Fox Hills formation with a different name. The Fox Hills formation is of little importance to the coal industry of Montana.
**Bearpaw Formation.** The Bearpaw, Judith River, Claggett, and Eagle formations make up what is known as the Montana group. The Bearpaw is stratigraphically below the Fox Hills throughout most of central and eastern Montana and is remarkably persistent and uniform in character and thickness. In most places it is about one thousand feet in thickness.

Lithologically, the formation is a soft gray gumbo-like marine shale with a large amount of inter-mixed clay. The formation is thickest in the eastern part of the state, gradually thinning out and becoming more sandy until it is unrecognizable as the Bearpaw near the western shore line of the sea in which it was deposited. Apparently this shore line was near the present Rocky Mountain front. Gypsum and bentonite are scattered throughout the formation.

**Judith River Formation.** Underneath the Bearpaw shale is the Judith River formation. It can be recognized throughout the state although its lithologic character and the sequence of beds differ from place to place. Generally, the Judith River formation consists of a series of alternating beds of sandstone, clay, and shale including some carbonaceous members the whole mainly of fresh water origin. In the central and northern parts of Montana occur oyster beds a few feet in thickness with coal seams above and below. Also, in the central part of the state the beds may show a greenish to olive-drab tinge which is due to an arkosic character. The Judith River beds in central Montana were the result of deposition along a north-south coastal plain between a mountainous area to the
west and a sea extending eastward, the shore line being somewhere in the eastern part of the state.

Northward into northern Montana and Canada the formation grades into what is known as the Belly River series. In Teton County a formation equivalent in part to the Judith River is known as the Two Medicine formation. It is the best coal producer in the areas where it is exposed.

Eastward from central Montana the Judith River sandstones thin out and change in character until they may be just a fraction of an inch of sand interbedded with shale. In North and South Dakota the equivalent formation is a marine shale which has been named the Pierre. Usually this is a soft shale, mainly dark gray or greenish gray and often contains calcareous concretions and abundant limestones.

All in all, the Judith River formation is quite important to the coal industry of Montana being one of the principal producers in the central and northern parts of the state.

Claggett Formation. The Claggett shale, which is about 500 feet thick, lies stratigraphically below the Judith River formation, and is the result of a marine invasion which was very similar to that which deposited the Bearpaw shale. In some localities two members of the Claggett are found. The upper member is a series of alternating sandstones and shales, and is chiefly sandstone at the top. Marine fossils are found in this member. The lower member is a marine shale
very similar to the Bearpaw shale. In fact, the Claggett and Bearpaw shales are so alike in type areas they can be distinguished only by field relationships or the most detailed examination of fossils. The sandstones of the upper member appear in central Montana, particularly near Harlowtown, and become increasingly more plentiful to the westward while the shale part of the formation decreases.

Coal in commercial amounts is not found in the Claggett formation within the state.

Eagle Formation. The Eagle formation, which lies stratigraphically below the Claggett shale, is mainly a sandstone with a thickness of two to three hundred feet. To the east of a line from near Hardin to Malta the formation thins out or becomes shaly or does both, and is not easy to recognize. Outcrops of this formation near Billings and Winnett are characterized by massive sandstone cliffs. Some marine fossils are found in the eastern part of the state, but most of the formation was land-laid. The formation differs from place to place only to a small extent. In the central Montana area it shows three members in the formation. The upper is a gray sandstone with some shale beds, the middle division is a dark colored shale containing thin beds of carbonaceous shale, and the bottom member is a white or buff massive sandstone. In the southern part of the area the carbonaceous shale is replaced by thin-bedded shaly sandstones while the basal sandstone is a dirty gray to brownish color. Near the
eastern state line, a sandy zone within the Pierre shale has been correlated with the Eagle formation. In northern Montana the basal member becomes a conspicuous sandstone called the Virgelle.

The only commercial occurrence of coal in this formation is the beds in the shale zone in the Bridger field a short distance southwest of Billings, and in the Bozeman, Livingston, and Electric fields.

Colorado Group. Throughout the greater part of the state a group of marine shales with some sandstone known as the Colorado group underlies the Eagle sandstone. These shales are remarkably persistent over great areas in lithologic character and thickness which averages about 2000 feet in most places. In the southern part of Montana the formation can be quite easily split into five sub-formations or members, which from top to bottom are the Niobrara shale, Carlile shale, Frontier shale and sandstone, Mowry shale, and Thermopolis shale. In the central and northern parts of Montana the formation is chiefly a dark-gray to black fissile shale which cannot readily be split into sub-formations, and for this reason the group is considered as one unit. Prominent members of the formation may have special names in some localities.

In all probability, the Colorado group of shales was laid down during a marine invasion which was quite extensive and lasting. There are no coal deposits of commercial importance associated with the formation, although northwest of Great Falls thin dirty seams occur locally.
Kootenai Formation. The Kootenai formation, Lower Cretaceous in age, is the oldest coal producing formation in Montana as well as one of the most important. The Kootenai formation is generally shale and sandstone of terrestrial origin. In the northern and central parts of the state the formation usually consists of interbedded red and gray shales and drab sandstones. It can easily be told from the overlying Colorado group by the more or less brilliant colors present, red (due to iron oxide) being the most prevalent. The sandstones in the northern half of the state are more plentiful in the bottom part of the formation while shale is more plentiful in the top part.

One of the most characteristic features of the formation is the usual presence of beds of the so-called "salt and pepper" sandstone near the base of the formation. This effect is caused by the presence of small particles of black chert which give the sandstone a peppered appearance.

The Kootenai formation is often involved in arguments concerning geologic names. In the south-central portion of the state and in northern Wyoming the name Cloverly formation is applied to this group of sediments. In Alberta either Kootenai or Blairmore is used while in the Black Hills the formation is probably represented by sediments of the lower part of the Dakota group.

Thicknesses for the formation differ from place to place, but in general they average about 500 feet. In the Glacier Park region a thickness of 1200 feet has been
measured, but it thins eastward and southward. In south-central Montana the Cloverly formation is about 300 feet thick and the Dakota group of the southeastern part of the state is about 250 feet in thickness.

Apparently the sediments composing the Kootenai were laid down on a piedmont plain which was east of a mountainous area in Oregon, Washington, and British Colombia. Terrestrial fossils are found in many places. Swampy conditions evidently existed in several areas as fairly thick coal beds occur from place to place throughout the central part of the state where some coal seams are quite persistent. For example, the Great Falls-Lewistown coal seam near the base of the Kootenai can be traced discontinuously for over one hundred miles. Black shales are frequently associated with the coal beds.

Structural Geology

Important coal deposits in Montana are almost exclusively confined to that portion of the Great Plains which lies in central and eastern Montana. Some coal beds exist near the edges of mountainous areas, but only rarely are these important.

The structural geology of eastern and central Montana is fairly well known as it has been mapped to a large extent by competent oil geologists. In general it may be said that Montana can be divided into three parts by the geologic structures. These are: (1) the folded
and faulted mountainous area occupying roughly the western
one-third of the state; (2) the central one-third of the
state which is a plains region with flat-lying strata and
a few isolated uplifts; and (3) the eastern one-third of the
state which is a plains region composed of flat-lying un-
disturbed sediments cut in places by river valleys.

The mountains of the central part of the state
often appear as isolated "islands" surrounded by plains.
These mountains show three different types of structure, namely;
igneous intrusions into sediments forming laccoliths, extru-
sive areas of igneous rocks which flowed onto the level plains,
and large assymmetrical folds caused by deep seated distur-

bances.

Great domes and uplifts divide eastern and central
Montana into irregular areas according to structural features.
The uplifts do not necessarily have high relief, but they can
be determined by the exposed beds. Some of these uplifts are
low hills which have some influence on topographic features
by determining the courses of the streams in the particular
areas where they occur.

The general structure of eastern and central
Montana can readily be seen on Plate III which originally
appeared as Plate II, Memoir 2, of the Montana Bureau of
Mines and Geology. It is a series of cross-sections through
the state, and shows most of the important structural features
such as uplifts and basins.
More detail structural geology is given in the descriptions of the coal fields and areas included in this report. Relationships between the coal deposits and the structural features of the areas are clearly pointed out, and in a few cases cross-sections of the areas accompany the discussions. Folding and faulting will be included in these discussions, and will not be considered at this time.

CHARACTERISTICS OF COAL

Definition

Coal is rather difficult to define, although many attempts to do so have been made. Webster's Dictionary states that coal is "A black or brownish-black, solid, combustible mineral substance formed by the partial decomposition of vegetable matter without free access of air, under the influence of moisture, and, in many cases, of increased pressure and temperature." Ries* differs from this slightly, stating that coal is a stratified rock formed from the accumulation and decay under water of vegetable matter, and its subsequent consolidation. The name itself was probably derived from the Anglo-Saxon "col" meaning to blaze, or from the Latin "calere", to be hot.

Origin

Coal is formed by a series of complex stages beginning with elements such as plant tissue, fibers, leaves, stems, seeds, and many others. The first step of any such

*Ries, H.; "Economic Geology"; p. 3.
formation is probably well shown by peat bogs which are swamps consisting of living plants at the top, a layer of dead plants next, and at the bottom a spongy, jelly-like mass. All three layers grade into each other. The colloidal mass at the bottom is usually brown to black and contains plant remains which are more or less completely altered. Water which contains different organic compounds constitutes a large portion of the mass and prevents the vegetable material from rotting or oxidizing as it would do if exposed to air. Submergence under water is absolutely essential in the formation of coal.

At the present time peat beds up to 50 feet in thickness are found, but even such an amount as this would be very inadequate in the formation of thick coal beds. Field studies show that broad, swampy, slowly sinking areas near sea level existed for long periods of time in the past, and these would be ideal for thick accumulations of vegetable matter. Late Cretaceous and Tertiary times were periods when such conditions apparently existed in Montana. Moreover, plant life at those times no doubt was very luxuriant, and thick coal beds are the results.

The flora of the Cretaceous period was somewhat similar to that found today. Tertiary plants were essentially the same as those of today. Burial of some sort took place, and peat bogs were gradually changed into the various grades of coal depending on temperature and pressure. From 16 to 30 feet of peat are necessary to make one foot of true coal
according to estimates. Pressure converts lignite successively into subbituminous, bituminous, anthracite, and even graphitic coal.

About the best coal-forming conditions existing today in the United States are found in the great Dismal Swamp of North Carolina and Virginia, and possibly the Everglades of Florida.

Fixed Carbon Ratio

The fixed carbon ratio of coal is the ratio of the amount of fixed carbon to the combustible matter (fixed carbon plus volatile matter). In general, within a given coal-bearing formation, the fixed carbon ratio is found to increase downward from the earth's surface, to be somewhat greater on anticlines than on adjacent synclines, and to be relatively high near faults and areas of intense folding. In two unconformable coal-bearing formations, the fixed carbon ratio is commonly higher in the older formation.

An isocarb map, one on which lines (isocarbs) are drawn through points of equal fixed carbon ratios, is included with this report. On this map it can be noted that higher fixed carbon ratios are found near the mountainous areas. In fact, one of the isocarbs roughly follows the rocky mountain front, while others are associated with the more recent mountains to the eastward, such as the Big Snowies and Little Belts. This map, however, is only approximate because analyses of coals of many critical areas cannot be obtained.

An interesting relationship between the fixed carbon
ratio and oil and gas has been noted in some areas, chiefly the Appalachian and Oklahoma oil fields. In these fields it was noted that when the fixed carbon ratio was 70 or above oil or gas seldom occurred. When it was between 65 and 70 gas sometimes was found, and from 50 to 65 oil was often found.

Types of Coal

Peat. Peat is vegetable matter in a partly decomposed and more or less disintegrated state, and represents much of the nearly black "soil" found in bogs or swamps. When wet, peat contains approximately 90% water. Dry peat may be fibrous and light colored, or compact, structureless, and dark brown or black. It burns with little smoke and if clean leaves little ash. Generally, the heating value of peat is about 5500 British thermal units.

Lignite. Lignite or brown coal (sometimes jet black in Montana) has a distinctly woody or less commonly amorphous texture. It occurs widespread in eastern Montana, and great reserves of it exist. It is sometimes a chocolate brown in color, but varies from yellowish to black. According to Tarr* lignite has an average fixed carbon content of 37.8% and a B.t.u. value of 7400. The specific gravity of lignite falls between 0.5 and 1.5. Lignite slacks easily and cannot be stored for long periods of time as fire from spontaneous combustion is possible.

Subbituminous. The next rank above lignite is known as sub-

*Tarr, W. A.; "Introductory Economic Geology".
bituminous and is very common in Montana. It is often called "black lignite" because of a woody texture. Some forms are amorphous and have a dull, waxy luster. The fixed carbon content of subbituminous coal ranges from 35 to 45 percent and the ash from 3 to 25 percent. The heating value of this grade of coal ranges from 8000 to 11000 B.t.u. This coal is a very good fuel, because it is clean and easy to ignite. However, some varieties slack badly if exposed, due to loss of water, and are unsuitable for storing or shipping.

Bituminous. Bituminous is commonly called soft coal, to distinguish it from anthracite, and it is found in some places in Montana. It is denser than lignite, deep black, and brittle usually breaking with a conchoidal fracture or cubical cleavage. It burns with a yellow smoky flame but with greater heating power than lower rank coals. Tarr states the B.t.u. value ranges from 12,800 to 15,200. The fixed carbon content ranges from 47 to 65 percent. It makes a better fuel than subbituminous coal for the reason it does not disintegrate on exposure to air quite as readily, and has a higher heat value.

Some varieties of bituminous coal are suitable for making coke. In Montana the only such coals are located in the Livingston and Electric fields.

Anthracite. Anthracite is a jet-black, hard coal with a conchoidal fracture and brilliant luster. It ignites with difficulty and burns with a blue flame. The fixed carbon
1. SIDNEY FIELD

V  10  20  30  40  50
F.C.  
A  
S  
M  

2. FORSYTH FIELD

V  10  20  30  40  50
F.C.  
A  
S  
M  

3. BULL MOUNTAIN FIELD

V  10  20  30  40  50
F.C.  
A  
S  
M  

4. RED LODGE FIELD

V  10  20  30  40  50
F.C.  
A  
S  
M  

KEY:
V  -- Volatile Matter
F.C.  -- Fixed Carbon
A.  -- Ash
S.  -- Sulphur
M.  -- Moisture

5. GREAT FALLS FIELD

V  
F.C.  
A  
S  
M  

6. MILK RIVER FIELD

V  
F.C.  
A  
S  
M  

7. ELECTRIC FIELD

V  
F.C.  
A  
S  
M  

INDEX MAP

TYPE COALS OF MONTANA
content averages 95.6 percent and the heating value averages 14,400 B.t.u. It represents the end of the change from vegetable matter to coal. No anthracite is found in Montana.

Coal Structures

The outcrop of any coal bed if not soil covered is usually easy to recognize by its color and character. The outcrop material, unless it is comparatively fresh, is disintegrated and mellowed, the wash from it mingling with the soil, and if the outcropping bed is on a hillside, often extending some distance down the slope. In Montana many outcrops are burned, forming what is known as clinker or scoria. Wherever the coal has been burned, the strata above have usually been baked to a large extent often forming a brick-like substance, usually red in color.

Ordinarily coal beds are interbedded with sandstones, shales, and clays, although limestones and conglomerates are occasionally found in the same vicinity. The number of beds may vary from one as in the Great Falls coal field to almost any number. In Montana, for example, 26 workable beds are found in the Bull Mountain field.

Only in very rare cases are coal beds or seams found to be uniform in thickness over large areas. As a general rule, the beds may range in thickness from a few inches in one place to several feet only a short distance away. This irregularity is due in most cases to variations in thickness of vegetable accumulations, but in some cases as in the Electric field to local squeezing of the bed after it has been formed.
Partings are common in most coal beds. This parting or splitting is caused by the appearance of beds of shale which are often so thick that they split the coal seam into two or more beds. This shale is called "slate" by coal miners. A narrow splitting is called a parting.

When clay is mixed in with the coal in fairly large quantities the mixture is usually given the name "bone" coal. Bone coal may be classified as slate if it shows a good bedding, but technically it is a carbonaceous shale.

Faulting may be found in coal beds often badly crushing the coal on either side of the break. Normal, reverse, overthrust, and step faults are found with the number, kinds, and amount of throw varying greatly.

Chemical Composition

Essentially, coal is composed of carbon, hydrogen, and oxygen, but some ash and sulfur are usually present. Two methods of analyses are used today, namely, proximate and ultimate. For most industrial uses, and for determining rank, proximate analyses are used. Compounds in the coal rather than elements are determined by this method. Ultimate analyses (analyses for elements present) are used in determining whether or not a coal is suitable for coking.

Table 1. -- Proximate Analyses of Types of Coals.

<table>
<thead>
<tr>
<th>Kind of Coal</th>
<th>Age</th>
<th>Moist.</th>
<th>Vol.</th>
<th>F.C.</th>
<th>Ash</th>
<th>S.</th>
<th>B.t.u.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>Tertiary</td>
<td>31.3</td>
<td>42.3</td>
<td>19.5</td>
<td>6.8</td>
<td>0.80</td>
<td>7337</td>
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<td>Subbituminous</td>
<td>Cretaceous</td>
<td>21.6</td>
<td>27.2</td>
<td>47.0</td>
<td>3.6</td>
<td>0.37</td>
<td>9508</td>
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<tr>
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<td>Carboniferous</td>
<td>2.8</td>
<td>29.2</td>
<td>59.8</td>
<td>7.4</td>
<td>1.22</td>
<td>13991</td>
</tr>
<tr>
<td>Anthracite</td>
<td>Carboniferous</td>
<td>2.8</td>
<td>1.2</td>
<td>89.2</td>
<td>7.8</td>
<td>0.89</td>
<td>14298</td>
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</table>
Table 2. -- Ultimate Analyses of Types of Coals.

<table>
<thead>
<tr>
<th>Kind of Coal</th>
<th>Ash</th>
<th>C</th>
<th>H</th>
<th>O</th>
<th>N</th>
<th>S</th>
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</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>12.24</td>
<td>52.66</td>
<td>5.22</td>
<td>27.15</td>
<td>0.71</td>
<td>2.02</td>
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<td>4.79</td>
<td>58.41</td>
<td>5.06</td>
<td>28.99</td>
<td>1.09</td>
<td>0.63</td>
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<td>Bituminous</td>
<td>1.07</td>
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<td>4.77</td>
<td>9.39</td>
<td>1.62</td>
<td>0.45</td>
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<tr>
<td>Anthracite</td>
<td>4.67</td>
<td>90.45</td>
<td>2.43</td>
<td>2.45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MINING METHODS

A detail discussion of coal mining methods is not advisable in a report of this nature. For this reason, the following discussions are very brief and are intended to give the reader only a general knowledge of the methods employed in Montana. Two general types of coal mining are practiced, namely, open-pit mining and underground mining.

Open-pit Mining

Open pits are used in several of the coal fields of the state in removing small amounts of coal for domestic or local use. However, the largest open-pit coal mine in the world (so claimed by the operators) is also located in Montana at Colstrip. Colstrip is in the Forsyth coal field east of Billings. All mining is confined to the Rosebud bed which is 28 feet in thickness in this particular area. Operations were begun in 1922 by the Northwestern Improvement Company acting for the Northern Pacific Railroad. The first pit opened was one and one half miles long and 900 feet wide,
<table>
<thead>
<tr>
<th>Field</th>
<th>Kind of Coal</th>
<th>Age</th>
<th>Moisture</th>
<th>Ash</th>
<th>Volatile Matter</th>
<th>Fixed Carbon</th>
<th>B.T.U.</th>
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<tbody>
<tr>
<td>Big Sandy</td>
<td>Subbituminous</td>
<td>Upper Cretaceous</td>
<td>12.41</td>
<td>14.90</td>
<td>35.80</td>
<td>10.600</td>
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<td>Subbituminous</td>
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<td>Subbituminous</td>
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<td>19.80</td>
<td>54.70</td>
<td>0.73</td>
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<tr>
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<td>Subbituminous</td>
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<td>27.60</td>
<td>48.08</td>
<td>0.44</td>
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</tr>
<tr>
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<td>Lignite</td>
<td>Tertiary</td>
<td>15.35</td>
<td>28.27</td>
<td>73.20</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bituminous</td>
<td>Upper Cretaceous</td>
<td>24.10</td>
<td>27.60</td>
<td>48.08</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Upper Cretaceous</td>
<td>21.10</td>
<td>26.75</td>
<td>28.97</td>
<td>0.44</td>
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<td>26.75</td>
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<td>Bituminous</td>
<td>Upper Cretaceous</td>
<td>15.35</td>
<td>28.27</td>
<td>73.20</td>
<td>0.44</td>
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<tr>
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<td>Bituminous</td>
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<td>21.10</td>
<td>26.75</td>
<td>28.97</td>
<td>0.44</td>
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<td>Lignite</td>
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<td>11.69</td>
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<td>Lignite</td>
<td>Tertiary</td>
<td>11.69</td>
<td>22.10</td>
<td>26.14</td>
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</tr>
<tr>
<td></td>
<td>Lignite</td>
<td>Tertiary</td>
<td>11.69</td>
<td>22.10</td>
<td>26.14</td>
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</tr>
<tr>
<td></td>
<td>Lignite</td>
<td>Tertiary</td>
<td>11.69</td>
<td>22.10</td>
<td>26.14</td>
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<td></td>
<td>Lignite</td>
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<td>Lignite</td>
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<td>Lignite</td>
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<td>22.10</td>
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<tr>
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<td>Lignite</td>
<td>Tertiary</td>
<td>11.69</td>
<td>22.10</td>
<td>26.14</td>
<td>0.44</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Proximate Analyses of Some Montana Coals (data from various U.S.G.S. bulletins).
<table>
<thead>
<tr>
<th>Field</th>
<th>Moisture</th>
<th>Volatile Matter</th>
<th>Fixed Carbon</th>
<th>Ash</th>
<th>Sulphur</th>
<th>B. t. u.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull Mountain</td>
<td>13.4 - 20.7</td>
<td>27.8 - 33.2</td>
<td>40.6 - 52.3</td>
<td>5.9 - 7.8</td>
<td>0.39 - 0.80</td>
<td>10,350 - 11,180</td>
</tr>
<tr>
<td>Electric</td>
<td>1.9 - 5.2</td>
<td>19.4 - 35.3</td>
<td>40.1 - 56.4</td>
<td>17.9 - 23.6</td>
<td>0.52 - 1.33</td>
<td>9,880 - 13,290</td>
</tr>
<tr>
<td>Lewistown</td>
<td>6.9 - 18.9</td>
<td>24.9 - 30.2</td>
<td>41.8 - 48.3</td>
<td>7.3 - 21.9</td>
<td>2.72 - 6.05</td>
<td>8,887 - 10,615</td>
</tr>
<tr>
<td>Milk River</td>
<td>21.4 - 23.3</td>
<td>26.6 - 29.9</td>
<td>33.1 - 43.9</td>
<td>9.0 - 13.7</td>
<td>0.58 - 0.72</td>
<td>7,800 - 8,940</td>
</tr>
<tr>
<td>Scobey</td>
<td>29.1 - 43.9</td>
<td>5.6 - 29.7</td>
<td>25.4 - 34.2</td>
<td>5.8 - 9.1</td>
<td>0.31 - 1.36</td>
<td>5,940 - 7,500</td>
</tr>
<tr>
<td>Red Lodge</td>
<td>10.4 - 14.1</td>
<td>33.5 - 36.4</td>
<td>40.6 - 45.4</td>
<td>6.9 - 13.0</td>
<td>0.83 - 2.23</td>
<td>9,787 - 10,880</td>
</tr>
</tbody>
</table>

Table 4. --- Range Analyses of Some Montana Coals.

This chart shows how much coals may vary in a single field. Many of the Montana coals lie on the border between lignite and subbituminous while others lie on the border between subbituminous and bituminous. Note the differences between the high rank bituminous found in the Electric field which is suitable for coking and other coals listed.
and contained about 7,000,000 tons of coal. This has been worked out, and another pit containing over 11,000,000 tons of coal two and one-third miles long and 900 feet wide has been opened.

All mining is done by electrically operated machinery with the electricity being brought from a distance of more than 100 miles.

Two stripping shovels weighing 1100 tons and 500 tons respectively and a stripping drag line are employed. In regular operations the overburden of about 40 feet is removed by the stripping shovels and drag line, and cast across the top of exposed coal into the excavation from which coal has previously been removed by the loaders. These loaders are two shovels equipped with eight-cubic-yard buckets and have a weight of approximately 300 tons each. They lift coal directly from the bed and deposit it in gondola cars on the railway, ready for use, at the rate of about nine tons of coal every 70 seconds. In a 24 hour period the two loaders could handle an estimated 20,000 tons of coal. Only one operator per shovel is required.

The stripping shovels can pick up about 15 tons of overburden and deposit it 300 feet away. When a portion of the pit is completed, it looks like a chain of mountains due to long piles of waste. The operation has several steps: stripping off the overburden; removing the coal; and then replacing the overburden in the coal-less hole. Stripping and loading shovels travel the entire length of the pit.
taking a certain width of coal out before turning.

The average output per man is nearly 60 tons of coal per shift as compared with four to six tons per man per shift in underground mining. Average production is about 1300 tons of coal per eight hour shift.

Underground Mining

Because of the frequent presence of explosive dust and gas thorough ventilation is more important for coal than for metal mines. This requires the driving of development openings in sets in which fresh air enters by one or more openings and after passing through the workings the foul air leaves the mine by other openings.

The commonest type of coal mining practiced in the United States is the "room-and-pillar" method, and can be very briefly described as the driving of adits or development entries, then the branching out from this entry, and mining out the coal leaving pillars of the coal to support the roof. In most cases a systematic method of some sort is used in laying out the rooms and pillars. Usually the rooms are turned off at right angles to the entry in one or both directions, depending on the system of mining and the dip of the seam. The opening into a room is called the neck, and the room is then widened on one or both sides with the average width of the rooms equal to 24 feet. Robbing or drawing pillars consists in removing the coal left for roof support after the first-mining has been completed. The character of the roof and
floor, texture of coal, thickness and dip of seam, presence of gas, and other local conditions all influence the method of work and the time at which it should be done. There are two general systems: robbing during the advance and robbing on the retreat. Recovery of coal by room-and-pillar methods runs from 55 to 92 percent.

The other main type of coal mining used in the United States is the "longwall method" which is not as commonly employed as room-and-pillar methods. The fundamental principle of this method is the complete removal of the entire seam in one operation by carrying a continuous working face, leaving no pillars, and allowing the roof to cave behind the face. A large pillar is left to maintain the hoisting and air shafts. As the face is advanced, the roof between it and the shaft pillar caves. For this reason, packwalls on each side of the numerous haulageways must be maintained through the caved area to reach and ventilate the working face. This method is known as longwall advancing. In some cases an area is developed by haulageways, and then coal is mined by working back toward the shaft. This is known as longwall retreating. Recovery of coal by longwall methods is approximately 100 percent.

In common with other mass-production industries, coal mining seeks to eliminate hand labor. In hand-loading mines the labor cost probably exceeds 60% of the total cost of production. Coal operators are therefore adapting the
established methods of room-and-pillar, longwall, and modified longwall to the use of mobile loaders, conveyers, shaking chutes, and scrapers. Besides mechanical loaders, electric coal drills and track mounted cutting and shearing machines of large capacities are often used.

MARKETS AND PRODUCTION

The markets for Montana coal are found chiefly within the state because of an abundance of coal in all regions adjacent to the state except those to the west.

Ninety-five percent of Montana coal production comes from the Forsyth, Red Lodge-Bear Creek, Bull Mountain, and Great Falls fields. None of the eastern lignite fields produce much, mainly because lignite cannot stand storage due to slacking. However, towns near coal deposits are usually supplied by truck haul from small mines.

Coal from the Colstrip mine in the Forsyth field is used by the Northern Pacific Railroad whose main line crosses Montana from east to west. Colstrip coal is not on the open market.

The field next to Forsyth in importance is the Bull Mountain field in Musselshell and Yellowstone Counties. The chief mines, at Roundup and Klein, supply much of the domestic market in southern and southwestern Montana and also the Chicago, Milwaukee, St. Paul & Pacific Railroad which crosses Montana nearly parallel to the Northern Pacific.
Coal from the Red Lodge-Bear Creek field in Carbon County competes with Roundup coal in many of the markets in southwestern and southern Montana. Also, some coal is supplied to parts of Wyoming from this field. The Red Lodge-Bear Creek field is serviced by the Northern Pacific and Montana, Wyoming & Southern railroads.

About ten or fifteen miles southeast of Great Falls is a coal field centering around the towns of Belt, Giffen, Sand Coulee, and Stockett. This field supplies the Great Northern Railroad and much of the domestic market of Northern Montana.

Coal from the Lewistown field is mined from the same seam as that at Great Falls, but at present there is only a local market. The district is served by the Great Northern and Chicago, Milwaukee, and St. Paul railroads.

The Milk River field, near Havre, supplies only local markets to which the coal is hauled in trucks.

At one time, Butte and Anaconda smelters were supplied with coal from the Bridger field which has been abandoned. The Livingston (Trail Creek) and Electric fields supplied Butte and Anaconda with coke in the past, but these districts are almost abandoned at present.

The discovery of natural gas in Montana has curtailed coal production to quite an extent. Practically all of the larger towns in the state are supplied with natural gas from some one of the nine widely spaced commercial gas fields. There are also eight commercial oil fields within
Montana, and the use of oil-burning furnaces and stoves has cut into the coal markets to some extent. Hydro-electric power has also influenced coal markets to a slight extent.

Coal was first mined in Montana in the year 1880, and between 1894 and 1908 annual production ranged between one and two million tons. Since 1908 annual production has ranged between 2,000,000 and 4,600,000 tons with peak production in 1918 when 4,532,505 short tons were mined. Peak value of annual coal production was attained in 1920 when 4,413,866 tons were mined with a total value of $13,923,000. In recent years the value of coal mined within the state has been close to four million dollars annually. Total production for the state since coal mining began is approximately 130 million tons.

Montana coals are available for commercial shipment in 8-in. lump; 8x4-in. egg; 4x2-in., 3x2-in., 2x1\(\frac{1}{2}\)-in., 2x1\(\frac{1}{4}\)-in., 1\(\frac{1}{2}\)x1-in., 1\(\frac{1}{2}\)x\(\frac{3}{4}\)-in., and 1\(\frac{1}{2}\)x3/4-in. nut; and slack sizes.

Montana coal is used chiefly as an industrial and domestic fuel. The railroads crossing Montana are the largest consumers of the bituminous and subbituminous coals.

The possibility of building up any industry using coke for fuel is very remote in Montana because only a very small amount of coal suitable for coking exists within the state.

Gasoline and other hydrocarbons have been successfully produced from coal by destructive distillation. At the
<table>
<thead>
<tr>
<th>COUNTY</th>
<th>TONS</th>
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Table 5. --- Coal Mine Production by Counties, 1939. Modified from the Montana State Board of Equalization, Ninth Biennial Report, July 1, 1938 to June 30, 1940.

This table shows Montana coal production by counties for 1939. Rosebud County is the largest producer, mainly because of Colstrip. Notice the variation in the average price per ton due to location of markets, grade of coal, and many other factors.
present time this gasoline costs more to produce than that resulting from the cracking of crude oil, and so it cannot compete on the open market with it. However, in the future, it is possible that coal may be put to this use.

Producer gas suitable for industrial use can be manufactured from lignite of which Montana has great reserves. If in the future natural gas supplies are exhausted, producer gas may become very important, thereby increasing the value of Montana lignite deposits to a great extent.

Recent experiments carried on by the United States Bureau of Mines have shown that low grade coals such as the subbituminous and lignite found in Montana are more adaptable to processes of liquifaction and hydrogenation than higher grade coals. Also, these coals seem to be the most suitable for the production of some synthetics and plastics. On this basis, it seems reasonable to suppose that new industries using Montana coal as raw material may be developed in the future.

COAL FIELDS

Great Falls Coal Field

The Great Falls coal field is divided into two sections, the Great Falls coal field proper, and the Hound Creek district which is a southwestern extension of the Great Falls coal field. It covers 1500 square miles situated
mainly in the north-central part of Montana. It extends along the Rocky Mountain front range from a point 10 miles west of the Judith River to a short distance beyond the Missouri and lies mainly in Cascade county.

The area lies within a zone which is partly plains and partly mountains, and topographic features of each are found. Mainly it is a broad gently sloping plateau bordering the adjacent mountain ranges.

The oldest rocks in the district belong to the Carboniferous age, but these along with Jurassic rocks are unimportant in their relationship to the coal. The important strata belong to the Kootenai formation which is topped by the Colorado shale, lying unconformably upon it.

The structure of the area is quite simple in the plains portion, as the strata are nearly horizontal having a small dip to the northeast away from the mountains. There is a series of shallow synclines and low anticlines present along with several minor faults especially in the vicinity of Belt and Stockett. The Belt mountains are an anticlinal uplift.

Fisher* states "Throughout the Great Falls coal field the coal occurs in the lower part of the Kootenai, or Lower Cretaceous rocks, mainly at a horizon about 60 feet above the base of the formation. Coal of workable thickness is not continuous, however, at this horizon, but varies locally."

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The coal itself is a medium-grade bituminous which is superior to Red Lodge, Bridger, and Sheridan coals but is comparable to Cambria coal of the Black Hills.

There are several fair sized mines in the area as the coal is the best to be found in that part of the state. In the Hound Creek district are small mines which supply local demand, but there is not enough coal and it is too low grade for much future development.

Lewistown Coal Field

The Lewistown coal field is in the center of Montana mostly in Fergus County. It covers an area of 1500 square miles with the Little Belt and Big Snowy mountains in the southern part of the field. The rest of the area is plains. The coal seams are found in the foot hills of the mountains.

The oldest rocks in the region, the Morrison formation, are of Jurassic age. Above this is the Kootenai formation of Lower Cretaceous age which has a workable coal bed at the base. The rest of the exposed rocks in the area belong to the Upper Cretaceous period and are devoid of coal.

The structure of the field is quite simple with the beds dipping at a slight angle away from the Little Belt and Big Snowy mountains which are anticlinal in structure.

The coal is found at the base of the Kootenai formation but is not continuous throughout the field. There are four districts from which some coal has been mined. They are: (1) Sage Creek district which has one small mine supplying coal for local use, (2) Buffalo Creek district
with two mines working on one workable bed, (3) Warm Spring Creek district which is the largest (75 square miles) and has several mines present. Practically all of the Fergus County coal comes from this district.

The coal itself is practically the same as that found in the Great Falls coal field, being a low-grade bituminous. Development of the field is limited to some extent by competition from other fields which are better situated with respect to markets and to other economic conditions affecting mining of coal.

Milk River Coal Field

The Milk River coal field lies in the north-central part of Montana on the northwestern edge of the Great Plains. The area has no outstanding topographic features being practically flat, except as gullied by erosion.

The oldest rocks belong to the Cretaceous period and make up the Montana group of formations. Above these are the Tertiary rocks comprising the Fort Union group in which lignite is found.

Pepperberg described the structure of the area as follows: "These rocks, (sediments) which were originally approximately horizontal, have been subsequently disturbed by numerous faults and folds, which make the working out of the stratigraphy rather difficult. They (the faults) are in general closely associated with folds and for the most part are of the thrust type, although a few normal or

*Pepperberg, L. J.; U.S.G.S. Bull. 381, p. 88.*
tension faults were observed. The disturbances mentioned
have caused lateral and vertical offsets of the coal beds, in
many places tilting them to high angles."

Most of the coal occurs in the upper part of the
Judith River formation, from 10 to 150 feet below the base
of the Bearpaw shale. This coal has been classed as a fair
grade subbituminous. Most of the beds are lenticular in
shape with thicknesses from a fraction of an inch to nine
feet. Thinner beds and lower grade coals are present in
the eastern part of the field. All development work has been
restricted to local prospects and strip pits.

Cleveland Coal Field

The Cleveland coal field lies for the most part
between the Fort Belknap Indian Reservation on the east and
the Bearpaw Mountains on the west, in Blaine County. The
northern end of the district is only six miles south of Milk
River.

The oldest rocks are Mississippian in age and belong
to the Madison formation. Above this is a dark gray fine-
grained limestone rich in fossils which has been called Ellis
and is Jurassic in age. This in turn is overlain by the
Kootenai formation, Colorado shale, and Montana group which
are of Cretaceous age. The whole is covered locally by
Quaternary glacial drift, bench gravel, and alluvium.

The most important structural feature of this area
is the Bearpaw Mountains. All the beds in the region dip sharply away from them and gradually level out until they are nearly horizontal. There are also several unimportant faults in the area.

Coal is found only in the Judith River formation, and none south of Peoples Creek. The thickest bed is only two feet and this is very pockety in nature. The coal is black to brown in color and has a brown streak. Analysis shows it is about the same as Milk River coal which is subbituminous.

There is one mine in the district which supplies coal for local use only.

Musselshell - Judith
(Winifred Coal Field)

The Winifred coal field lies in the central part of Montana and is from one to thirty miles wide. It extends from Musselshell northwest to Judith a distance of 125 miles and covers approximately 1400 square miles.

The Colorado shale is the oldest formation found in this area. Above it is found the Montana group which is composed of the Eagle sandstone, Claggett shale, Judith River formation, and the Bearpaw shale. The youngest formation is the Lance.

The dominant structure of the area is a broad symmetrical anticline in the eastern part with several small
folds superimposed. A dome was produced by the uplift of Black Butte and the North Moccasin Mountains. Faults are not important in the area except along the Judith River.

The Eagle sandstone may contain coal of economical value in the northern part of the area, but a survey is necessary. There is some coal in the Judith River formation, but it is unimportant. Analysis shows the coal is high in moisture and ash and low in calorific value. On this basis it would be classed as low grade subbituminous. The coal in the Eagle is important locally at the present time because of the lack of wood for fuel in the area. It may prove to be valuable in the future with development.

Blackfeet Indian Reservation

The area discussed includes most of Glacier and part of Pondera counties including the Blackfeet Indian Reservation and considerable area to the east.

The area is on the western border of the Great Plains at the foot of the Rocky Mountains which rise with wall-like abruptness. The plains are low plateau areas dissected by stream channels into bad lands, locally blanketed by glacial moraine.

The stratigraphy for this area is a little different from that in most of the regions discussed. The oldest formation is the Kootenai followed by the Colorado shale and Montana group with the following members: Virgelle sandstone, Two Medicine, Bearpaw shale, and Horsethief sandstone. Next is
Generalized profile and structure section from Hysham south along divide between Sarpy and Tullock creeks to south edge of Tullock Creek Field. Taken from U.S.G.S. Bull. 749, p. 6.

Cross Section of Red Lodge-Bear Creek Coal Field from U.S.G.S. Bull. 341, p. 98.

Cross Section showing regional southeastward slope of strata in the Scobey Lignite Field, Montana, from U.S.G.S. Bull. 751, p. 169.

Cross Section of Blackfeet Indian Reservation from U.S.G.S. Bull. 621, p. 128.
the St. Mary River formation and the youngest formation is the Willow Creek.

Structurally the area can be divided into two units, namely, the eastern part where the beds are nearly horizontal, and the western part adjacent to the Rockies where the rocks have been folded and faulted to an unusual degree.

All the coal is medium-grade bituminous, and is found at five horizons, three in the Two Medicine and two in the St. Mary River formation. There are five areas in the undisturbed rocks from which coal may be obtained and one in the disturbed rocks which is fairly important.

There has been practically no development in the field at the present time.

Big Sandy Coal Field

The Big Sandy coal field lies in north-central Montana in Choteau County. It lies north of the Missouri River, and west of the Bearpaw Mountains. It has a total area of about 345 square miles.

The oldest rocks in the area belong to the Colorado shale which is Cretaceous in age. This formation is overlain by the Montana group which is made up of the following members: Eagle sandstone (250-300 feet thick), Claggett (350-500), Judith River (500) and the Bearpaw whose thickness was not determined. Above these formations are rocks of Tertiary age making up the Fort Union group. The whole area is covered to a certain extent by glacial drift, bench gravel, and alluvium, all of Recent age.
There is no major structural feature in the field, but the original attitude of the rocks has been disturbed locally in many places by faults. Most outcrops are found only in coulees as the area as a whole is covered by alluvium and glacial drift.

The best grade of coal and the thickest beds are found in the Fort Union formation. The Eagle sandstone has a zone 50 to 100 feet thick in the middle of the formation which has a few coal beds, the thickest being not more than two feet. Thin beds of no economic importance are also found in the Judith River formation.

The coal in general is pitch black with a black streak. It has a bedded structure and is high grade subbituminous. There are two small mines in the area but they have to compete with the Great Falls field and for this reason and because the productive area is small, the field will probably never be very important.

Livingston and Trail Creek Coal Fields

Formerly the Livingston and Trail Creek fields were considered as two, but investigation has revealed that the beds are continuous and for this reason it is now considered as one field. It is in Park, Gallatin, and Sweetgrass Counties in the southern part of Montana to the north of Yellowstone National Park. It extends from Boulder River west to within six miles of Bozeman and was formerly known as the Bozeman field. It covers an area of about 300 square miles with the chief drainage being furnished by the Yellow-
stone River.

The topography is very rough as the area is bordered by mountains to the south and southwest. The altitude ranges from 4500 to 7000 feet above sea level.

The oldest exposed rocks are part of the Kootenai formation which is 500 feet thick in this area. Above this is the Colorado shale which has a thickness of 3700 feet. The uppermost formation is the Montana group with a thickness of about 5750 feet. Five thousand feet of this is made up by the Livingston water lain volcanics.

Folding is pronounced with folds and faults numerous in the west. The southern boundary is a mountain uplift along with minor folds. In the southeast corner of the field a big fault comes in from some outside source and cuts off the coal strata.

There are four mining districts within the field, but all are shut down at the present. At one time the field supplied some coke to Butte and Anaconda.

There is a wide variation in the grade of the coal, but most of it makes a fairly good coke. It is classified as a medium-grade bituminous coal. The coal beds are found in the undifferentiated Montana group.

If there is ever a demand for coke in this region again, undoubtly this field will again become important.

Electric Coal Field

The Electric is a small and at present unimportant
field in Park County and covering an area of about 20 square miles.

The altitude is more than 6900 feet above sea level and the topography ranges from high mountainous ridges to a deep valley cut by the Yellowstone River.

The oldest formation is the Quadrant which is Pennsylvanian in age and this is followed by the Phosphoria, the Ellis, the Morrison, the Kootenai, the Colorado, the Montana group (undifferentiated) and Tertiary lava flows.

Calvert states: "In general, the area may be said to represent a fault block narrowing to an apex north of Cinnabar Mountain and depressed relatively many thousand feet."

The coal was mined from two areas, one at Electric and another at Aldridge. There are three beds varying in thickness from 3'4" to 4'2".

The coal is classified as bituminous with a high ash content. It is very good coking coal, and before natural gas was employed as a fuel, it was coked and sent to smelters in Butte and Anaconda.

Because of its size and the advent of natural gas, this field is no longer producing in any quantity, although the coal is very high grade.

Crazy Mountains Area

The Crazy Mountains area, really a part of the

Livingston field, is L-shaped and lies in Sweetgrass, Park, and Gallatin Counties. It is sixty miles long (east to west) and forty miles wide (north to south). The topography is gentle with low relief, but the area is flanked by mountains several thousand feet high.

The exposed rocks are Kootenai, Colorado shale, Montana group, and Laramie formations of Cretaceous age, and Livingston and Fort Union formations of Tertiary age.

According to Stone*, the geology of the area is complicated by the intrusion of igneous rocks in the form of dikes, sills, and laccoliths. These are most numerous in the vicinity of the Crazy Mountains. Igneous rocks of the Crazy Mountains have intruded the sediments and caused the formation of domes, folds, and possibly faults.

None of the coal of the region is of economic importance except in a small area west of the Crazy Mountains on the head of Sixteenmile Creek. Some of the coal occurs in the Eagle sandstone but it is impure. There are lenses in the Judith River, Laramie, and Fort Union formations.

According to the United States Geological Survey there are no workable beds in the area, and the land is not classed as coal land.

Red Lodge Coal Field

The Red Lodge coal field is at the foot of the Beartooth Mountains in Carbon County, northeast of Yellowstone.

National Park and between Yellowstone River and Clark Fork. It has an area of 64 square miles, one half of which is underlain by coal. The topography is rough and because of this the field is divided into two districts.

The only formation in the field is the Fort Union which seems to have three members in this area. The lowest member is barren of coal and is composed of yellowish sandstone and shale. It has a thickness of about 5700 feet. The middle member is the productive member. It is 825 feet thick and is composed of varicolored sandy shale, some soft yellow sandstone, carbonaceous shale, and workable coal. The upper member is sandstone and shale with very little carbonaceous material, and is barren of coal. It is 1,975 feet thick.

Woodruff* says that structurally the rocks form part of an eroded monocline which dips southwestward from the Pryor Mountains to the Beartooth Range, where it is terminated by a fault having a throw of several thousand feet.

The field is limited on the south by a gradual pinching out of the beds, on the east and north by the line of outcrops, and on the southwest by a great fault. The workable coal beds are distributed through about 800 feet of strata, with a total of 71 feet of coal in beds three feet or more in thickness. Beds can be traced continuously throughout the field.

The field is divided into two districts by the topography. These districts are the Red Lodge district, which has one productive mine, and the Bear Creek district, which has mines operated by five coal companies. This district was formerly known as the Bear Creek field, but is now included in the Red Lodge field.

The coals are high-grade subbituminous or nearly bituminous and have a black color, pitchy luster, irregular joints, and medium hardness. It is estimated that there are 1,238,986,581 short tons of recoverable coal in the field.

The district supplies much of the coal used in Montana with its chief markets at Butte, Anaconda, and Bismarck, North Dakota. All mining is done by room and pillar methods.

Bull Mountain Coal Field

The Bull Mountain coal field, one of the most important fields in Montana, is in Yellowstone and Musselshell counties between Musselshell and Yellowstone rivers. The Bull Mountains from which the field gets its name stand out as a divide between these rivers, but they lack the ruggedness of the mountains of western Montana. South of these hills the country is rolling.

The oldest rocks exposed are Upper Cretaceous in age and constitute the Bearpaw shale, which is 1000 feet or more in thickness. Above this is the Lance formation with
a thickness between 700 and 1500 feet. Tertiary rocks of the Fort Union group are above this, the lower formation known as the Lebo shale having a thickness of 200 to 300 feet, and the upper formation 1650 feet.

The structure of the area has been described as follows: "It (structure) consists of a large, shallow synclinal basin, having a general northwestward axial trend, and a rather accentuated lip at its northwestern extremity. The syncline merges on its northern border into a mild anticline whose flanks dip about 5°. The anticline is parallel on the north by a sharper syncline, the greater portion of which lies to the north of the area...."

The oldest coal in the area is in the Lance formation where several thin beds are found. At the base of the Lebo shale is the Big Dirty bed which is the only bed of any thickness in this formation. The upper member of the Fort Union contains the workable beds with 26 being found. Most of the beds are lenticular showing a wide variation in thickness.

For the most part the coal is a high-grade sub-bituminous or low-grade bituminous. It is soft and easily reduced to a fine granular mass. It has a black luster and compares well with other coals in the state.

The field is quite well developed around Klein and Roundup, principally because the Chicago, Milwaukee, St. Paul and Pacific railroad main line passes through or

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*Richards, R. W.; U.S.G.S. Bull. 381, p. 64.*
near these towns. There are also several other localities within the field where small amounts of coal are mined. The principle markets of the district are Butte and Billings.

Crow Indian Reservation

The Crow Indian Reservation is in Big Horn County in southern Montana on the western edge of the Great Plains. The maximum relief is 6500 feet from the Yellowstone River to the Big Horn Mountains. Nearly a complete geologic column is exposed in this general region with the oldest rocks being pre-Cambrian granite and the Wasatch formation of Miocene age, being youngest.

The Big Horn and Pryor Mountains extend northward into the Crow Indian Reservation where they are the major structural features. On the plains, which cover the greater part of the area the rocks are generally flat lying with numerous minor domes and anticlines and several belts of faulting in the western, southern, and northern parts.

Nearly all of the coal occurs in the eastern part of the reservation, being found in the Cloverly, Parkman, Hell Creek, Bearpaw, Lance, Fort Union, and Wasatch formations. Beds in the Tullock and Lebo shale formations are thin and with little value, but quite persistent. The Tongue River formation contains 20 beds with sufficient thickness to be workable, some of which have a great lateral extent.

The coal is subbituminous with a conchoidal fracture and black shiny luster. It weathers easily and quickly and
therefore is hard to store in bins for any length of time. The field is practically undeveloped with small amounts of coal mined for local use.

*Tullock Creek Coal Field*

The Tullock Creek coal field is on the east side of the Big Horn River near its mouth and along Tullock Creek, and it includes about 900 square miles. The region is a maturely dissected plateau across which the Big Horn and Yellowstone rivers have cut wide, deep erosion valleys.

The oldest exposed beds are the Claggett shale, upper Cretaceous in age. Above this is the Judith River formation which is overlain by the Bearpaw shale. The Lance formation is above this and it is divided into two members, the lower member and the Tullock member. Above the Lance is the Fort Union group which has two member formations in this region.

Rogers and Lee explain the structure of the area as follows: "The Tullock Creek field lies with an area in which the broad, shallow syncline connecting the Bull Mountain and Powder River basins is crossed by a structural upwarp that connects the Porcupine dome and an anticlinal spur of the Big Horn Mountains." In the northern part of the field the strata dip gently to the south while in the southern part the strata dip more steeply to the north and east. This causes a gently downwarped middle which is faulted to some extent.

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extent. Minor folds and faults occur mostly in the depressed zone in the middle. Displacement of faults is small.

Thin coal beds occur in the Tullock member of the Lance formation and some thicker beds occur in the upper division of the Fort Union. These beds have been burned extensively along outcrops and have reddened the overlying strata.

There are ten horizons in the Tullock formation, but they are not particularly important. Coal is also found in the Lebo shale, but it also is unimportant. Most of the good coal occurs in the upper division of the Fort Union where there are six beds from one to 24 feet thick. Much of this coal is unbroken by partings.

The coal is black in color and brittle when fresh. It has a bright vitreous luster, and some seams of lignite occur with it. From chemical analysis it appears to be subbituminous. The coal that is in beds 18 inches or more in thickness has been estimated at 1,919,700,000 tons of which 1,653,700,000 tons are in the upper division, 263,400,000 tons in the Tullock and 2,600,000 tons in the Lebo shale.

As yet the field is undeveloped, but it may possibly become important in the future.

Pine Ridge Field

This area lies in Custer, Yellowstone, and Big Horn counties. It is on the west side of the Bighorn River in the angle formed by its junction with the Yellowstone River. Coal bearing strata crop out on Pine Ridge from which the field got its name.
The area is on the boundary of the Great Plains on the extreme northern edge of the Bighorn uplift. Most of the strata lie nearly horizontal with the general dip being 1° northeast. There are several small unimportant folds and faults.

The oldest rocks are the Montana group of Cretaceous age. Above this is the Lance formation, the upper member of which is coal bearing. There is one bed of coal over 18" thick at the base of the coal bearing member of the Lance formation which is a good subbituminous grade. It is black in streak and color with a bright vitreous luster and no woody structure. It is fairly clean and pure comparing favorably with Roundup coal. Practically no development work has been carried out in the area, and none is expected because of the Roundup and Bear Creek coal fields which are fairly close. It has been estimated that there are 20,869,760 tons of coal, 60% of which would be recoverable.

Sheridan Coal Field (Northward Extension)

The Sheridan coal field includes parts of northern Wyoming and southern Montana. It occupies the western portion of a wide basin between the Black Hills and Big Horn Mountains with an area of 700 square miles north and south of the Wyoming-Montana state line.

The area is on the western margin of the Great Plains and has considerable relief (1500 feet). It consists of upland surface trenched by deep valleys bordered in many places by
steep slopes or cliffs.

Practically all the exposed rocks in the area belong to the Tongue River formation of the Fort Union group, with the only other formation found being the Wasatch of Miocene age. The area is in the northwestern part of the Powder River basin which is a great structural depression between the Big Horn Mountain uplift on the west and the Black Hills uplift on the east. The strata for the most part have a slight slope to the south and southeast with some minor anticlines and folds and only three faults have been found.

There are ten coal horizons, all in the Tongue River formation. The coal is subbituminous in grade and is usually found in thick beds free from partings. Most of the outcrops have been burned.

On the Montana side of the state line some small-scale operations are providing coal for domestic use. More development may be possible in the future, but because of competition from better situated fields, prospects are very slight at present. There is an estimated tonnage of 38,500,000,000 tons for the entire field which is probably too low a figure.

Rosebud Coal Field

The Rosebud coal field covers an area of 1050 square miles which is a very small part of the subbituminous and lignite coal fields of eastern Montana, Wyoming, and the western part of the Dakotas. This field lies south of Yellowstone River, adjoins the Forsyth coal field on the west,
Ashland field on the south, and Miles City field on the northeast. Most of the field is devoid of timber other than scrub pine, as it is badlands and rolling country. The maximum relief is 1075 feet with the highest altitude 3475 feet above sea level.

The exposed rocks belong to two series of formations, the Lance and Fort Union. The Lance is divided into two formations, the Hell Creek and the Tullock which are quite similar to each other; the Fort Union is divided into the Lebo and Tongue River formations.

Most of the beds lie nearly horizontal with the axis of a very shallow syncline following the valley of the Tongue River. There are some small folds, and two unimportant faults.

The coal reserves have been estimated at 1,171,000,000 tons of subbituminous in beds 1 1/2 feet or more in thickness. Approximately 85% of this coal lies in the Tongue River formation and 70% of this in beds over three feet thick. Altogether, there are eight mineable beds in the Tongue River formation and four in the Lebo shale.

The coal itself is shiny black with a conchoidal fracture and it disintegrates when exposed to air for a length of time. At the present time it is not mined commercially.

Ashland Coal Field

The Ashland coal field is in southwestern Custer, southeastern Rosebud, and northwestern Powder River Counties. It has a total area of about 975 square miles, and at the
present time its chief use is for grazing. The main drainage of the area is the Tongue River. The topography of this area consists of a series of benches or steps which are probably the remnants of an old plateau, since these benches are cut in many places by erosion.

The oldest rocks of the region are Tertiary in age and are a part of the Lance formation. The main formation in the area, however, is the Fort Union which has a thickness from 1300 to 1750 feet. This formation consists of two subformations, the Lebo shale which is about 160 feet thick and contains a few thin coal beds, and the Tongue River which is between 1150 and 1600 feet thick and has several coal seams. Overlying the Fort Union are gravels and alluvium of Quaternary age which have no bearing on the coal strata.

The main structural feature of the area is a broad geosyncline plunging gradually northeast with its axis roughly following the Tongue River valley. Most of the strata, however, lie nearly horizontal.

There are enormous reserves of coal in this area with many beds locally from 10 to 25 feet in thickness. Practically all of the important beds are found in the Tongue River formation.

The coal itself is black and fairly clean. It is quite brittle and breaks with a conchoidal fracture. It readily slacks when exposed to air for a length of time. From analysis, it is classified as subbituminous. The reserves in this field have been estimated at 10,757,749,000 tons in
five mineable beds. However, because there is no railroad into the area, all coal mined is for local use only, and the field probably will not be important for many years.

Forsyth Field

This is one of the more important fields in Montana, because the great strip pit at Colstrip is within this field. The field covers about 800 square miles in southern Montana, south of the Yellowstone River and along Tongue River. It includes parts of Rosebud, Treasure, and Big Horn counties. Geologically and geographically it merges with the Sheridan and adjacent coal fields.

The field lies in the Great Plains province and is a much dissected plateau into which the Yellowstone River and its tributaries have cut their valleys.

The oldest rocks are Cretaceous in age and belong to the Montana group of sediments. Over these are the Hell Creek and Tullock members of the Lance formation followed by the Lebo shale and Tongue River formations of the Fort Union group.

Dobbin states that: "The Forsyth field lies in a broad, shallow syncline or structural trough pitching gently southeastward, which connects the Power River Basin and the structural depression of the Bull Mountains." There are also some small inconspicuous anticlines and synclines in the area.

The coal is found in the Tullock formation, and the Lebo shale and Tongue River formations of the Fort Union group.

*Dobbin, C. E.; U.S.G.S. Bull. 812, p. 22.*
In the Tullock the coal is too thin and dirty to be of much value, and the only important coal in the Lebo shale is the Big Dirty bed which, as the name implies, is not a clean coal. In the Tongue River formation there are 8 beds from 3 to 30 feet in thickness in the lower 725 feet of the formation and 4 beds in the upper 1000 feet of irregular thickness. The Rosebud bed which is the one being mined extensively at Colstrip by the Northwestern Improvement Company is located 360 feet above the base of the Tongue River formation.

The field is well developed compared to most of them in Montana. Colstrip is said to be the largest open pit coal mine in the world and was discussed under mining methods. Besides this, there are several small mines in the area.

It has been estimated that there are 9,679,112,000 tons of coal of which 259,760,000 are recoverable by strip mining and 3,824,500,000 are recoverable by underground mining.

Custer National Forest

This is a relatively unimportant area covering about 950 square miles. It lies to the east of Tongue River in southeastern Montana and a little north of the Montana-Wyoming boundary line, merging with the Ashland field on its eastern side.

The only formation exposed is the Fort Union. The topography formed is of three types: (1) lowlands (2) badlands,
and (3) uplands. All the rocks lie nearly horizontal.

There are seven workable beds above Ashland, all of which are fairly constant in thickness and quality over the entire area. The grade is on the borderline between lignite and subbituminous, and the coal has a brownish cast when first mined but turns dark. It is mined locally from small strip pits.

Scobey Lignite Field

The Scobey lignite field is in the northeast corner of Montana 20 miles from the Montana-North Dakota boundary and just south of the Canadian boundary. It lies north of the Fort Peck Indian Reservation. It is part of the Great Plains area.

The oldest formation is the Bearpaw shale which is exposed in two small localities on the western border of the field. Above this is the Fox Hills sandstone with a thickness of about 80 feet. The next formation is the Lance. Above this is found the Fort Union group.

There are no outstanding structural features in the field, nearly all of the strata lying horizontal or with a gentle dip to the southeast.

The lignite is found in the Lance and Fort Union formations and is a brown coal not greatly changed from wood, and generally showing a woody texture. It slacks readily on exposure and therefore cannot be stored for a length of time. It is estimated that there are 8,971,100,000 short tons in beds 30 inches or more in thickness.
Plentywood-Scobey

The area in which the coal outcrops occur lies between Plentywood and Scobey in Sheridan County in the northeastern corner of Montana.

The oldest formation in this area is the Lance of which only about 300 feet is exposed. The other formation found in the area is the Fort Union, although the surface is blanketed by Recent alluvium and glacial drift.

There are no major structural features in the area and the beds lie nearly horizontal, dipping 10 feet to the mile eastward.

There is no coal in the Lance formation in this region, all of it being confined to the Fort Union. Five beds of lignite, with the thickest bed being the Richardson (two feet) occur at the base of the formation. Most of the local outcrops are too thin to use, although they are mined in places due to a shortage of other fuel.

The lignite has the typical physical properties of that grade, being dark brown to black, dense or woody in texture, and having a dull waxy luster.

There is not much promise of a future large development in this field, as the beds are not thick enough to mine to much extent.

Culbertson Lignite Field

The Culbertson lignite field in Valley County is in the northeast corner of Montana and covers an area of 1500
square miles. It extends from the Canadian boundary south to the Missouri River, and from the North Dakota boundary west to Big Muddy creek. The field is really a northward continuation of the Eastern Montana lignite field.

Beekly* states that: "In a general way the Culbertson field may be divided into three topographic units as follows: An area of prominent hills and broad valleys along the Missouri, an immense flat in the central and southwest central portion, and an area of closely huddled hillocks, ridges, and troughs in the northern part and along the eastern border of the field."

The oldest exposed formation is the Pierre shale of Upper Cretaceous age. This is followed in order by the Lance formation, Fort Union group, and Quaternary glacial drift and alluvium.

There is practically no important structural feature; the beds lie practically horizontal, and have undergone little deformation. The dip is about 20 feet to the mile.

Lignite beds occur abundantly and are fairly well distributed in all the strata exposed. There are at least 15 beds, six of which have thicknesses of over three feet in all places. The lignite is of very good quality for the most part. It is brownish black in color and has a woody structure and high moisture content. It slacks readily when exposed to the air for a length of time.

Twelve small mines and prospects in the area supply

lignite for local use, which is important because no timber is present. The estimated tonnage is 33,235,200,000 short tons with 18,464,000,000 tons of this recoverable.

Fort Peck Indian Reservation

The Fort Peck Indian Reservation also lies in the northeastern corner of Montana, partly in Valley County and partly in Dawson County. The Missouri River divides the field into two topographic units. North of the river are level plains for about 20 miles and then hills 200 to 500 feet high. South of the river are bluffs and hills grading into badlands and then into upland plains.

About 1000 feet of Pierre shale is exposed, and this is followed by the Fox Hills sandstone. Above these formations is 200 feet of somber colored sands and clays, probably equivalent to the Lance, containing a few beds of impure lignite. The Fort Union group overlies this. It is about 1000 feet thick. Lignite is also present in this formation.

Originally these beds were horizontal, but at the present time they dip gently toward the east because of a low anticline which has its center near Poplar. Also, there is a shallow syncline pitching southeastward a few miles east of Wolf Point.

Only a few of the lignite beds are of sufficient thickness to be of importance, and the beds differ greatly in quality, thickness and lateral extent, with the workable
beds found only in the Fort Union group.

The lignite is dark brown, and very tough with a woody structure. There is little development in the field and such lignite as is mined is used for local domestic purposes because of the lack of other fuel.

Richey-Lambert Coal Field

The Richey-Lambert coal field covers an area of 900 square miles along the divide of Yellowstone and Missouri rivers in Richland and Dawson counties.

The oldest rocks in the district belong to the Lebo shale formation of the Fort Union group. This formation is 300 feet thick. Above this is the Tongue River formation which has a thickness of about 950 feet. Above the Fort Union group are found Miocene gravels, Pleistocene glacial drift, and Recent alluvium.

The field lies on the west side of a broad shallow syncline whose center is near Williston, North Dakota. The beds are nearly horizontal but have a slight dip to the east. The maximum relief of the field is about 550 feet.

All the coal beds in the area are in the Tongue River formation of the Fort Union group. Apparently no definite correlation between the 12 mineable beds in the Richey-Lambert field and beds of other fields in eastern Montana has been made.

The coal itself is a good grade of lignite, nearly black with a brown streak, subconchoidal fracture, and woody
texture. All the beds are lenticular, and irregular in extent and thickness, with the maximum thickness ranging from 4 to 21 feet. There is an estimated 12,994,000 tons of recoverable coal in the field. At the present time it is used for local purposes only and mined in small strip pits.

McConé County

The McConé County field lies immediately west of the Richey-Lambert field in the central part of eastern Montana.

Bearpaw shale exposed along the Missouri River is the oldest formation in the area. It grades into the Fox Hills sandstone above and this in turn is overlain by the Lance formation. Above this is the Fort Union group which is the youngest strata in the area with the exception of glacial drift, gravel, and alluvium of Tertiary and Quaternary age.

Most of the county lies in a broad synclinal basin whose axis runs east and west, and lies in the southern part of the county. Strata lie nearly horizontal, and the maximum relief in the county is about 1100 feet. In the center of the county is the large Weldon fault which has been traced six miles in a southwest-northeast direction.

The oldest coal beds are in the Fox Hills formation but they are unimportant, being thin and irregular. In the Hell Creek formation of the Lance a persistent coal bed occurs at the top, with thin local beds in other parts of the formation.
Also small beds of coal, from five to thirty feet apart, occur in the Tullock formation. The most promising coal occurs in the Fort Union group with the Big Dirty bed at its base. There are many thick persistent coal beds in this formation and they may become important at some future time.

Numerous small mines and pits have been opened on the most promising seams of this county, but the total production does not amount to very much. Total coal reserves have been estimated at 24,938,432,000 tons mostly in the Tongue River and Lebo formations of the Fort Union group.

Sidney Lignite Field

The Sidney lignite field is in Dawson County, Montana, about midway between the north and south borders of the state.

The stratigraphy for this field is the same as that for the Glendive, Baker, and Terry fields with the oldest rocks belonging to the Pierre shale. Above this is 570 feet of Lance formation and on top of this is 1190 feet of Fort Union group. The greater thickness of Fort Union is due to the fact that it has not been eroded as much here as in other regions.

There are eleven beds of lignite important enough to be mapped, all of which are in the Fort Union. They are rather uniformly spaced with the two most important beds 90 feet apart and about 500 feet above the base of
the formation. The average thickness of these two beds is 4'9" and the maximum thickness is about ten feet.

The lignite resembles subbituminous coal at places, but is blackish brown in color. It is quite tough and not brittle, and has a woody texture. It weathers easily into black brittle fragments and slacks quickly when exposed to air.

Nearly all of the outcrops are burned forming a clinker or scoria which locally resembles lava, and which was formerly thought to be of igneous origin. This clinker has been a good aid in mapping the outcrops.

Tonnage in the field has been estimated at 23,329,830,000 short tons with 5,245,005,000 and 2,065,336,000 short tons in the two important beds. All development at present has been done by local ranchers who have mined small quantities for domestic use.

Sentinel Butte Lignite Field

The Sentinel Butte lignite field is mostly in North Dakota, but partly in Montana, in the drainage basin of the Little Missouri River. The topography is gently rolling plains locally cut into "bad-lands" by stream action.

Stratigraphically, the exposed rocks belong to the Fort Union group with the exception of some Oligocene rocks which cap certain buttes. The Fort Union group is 1720 feet thick in this region.
A small anticline whose axis runs northwest-southeast extends about 25 miles southwest of the area which causes the beds to dip to the northeast at about 20 feet per mile.

Nine beds of lignite are scattered throughout 900 feet of exposed strata. Besides these many other beds of less than one foot thickness are present. The beds are fairly continuous (24 miles in one case) and have a variable thickness. The two lower beds are burned leaving only a clinker zone which is as much as 100 feet thick in places.

The lignite is brown, tough and woody, and slacks rapidly on exposure to air. It has been estimated that within 1000 feet of the surface in beds 3 feet or more in thickness there are 33,126,269,000 tons of lignite. Lignite is mined to a small extent in open pits and drift mines to supply a local demand.

Glendive Lignite Field

The Glendive Lignite field, Dawson County, is in the eastern part of Montana about midway between the north and south borders. It extends from the north line of township 12 north to the south line of township 18 north and from the east line of range 52 east to the Montana-North Dakota border.

The lowermost formation is the Pierre shale of which 200 feet is exposed along Yellowstone River.
Above this is 570 feet of Lance formation, on top of which is 300 feet of Fort Union group.

The lignite occurs in one small bed in the Colgate member of the Lance, several thin lenticular beds in the upper Lance, and several beds one to four feet thick in the Fort Union group. One of these beds has been traced for over 150 miles along its outcrop. All of the lignite of economic importance occurs in the Fort Union with the lower beds being made up of black subbituminous coal. The lignite in the upper beds is brown with a brown streak and has a woody texture and a choncoidal fracture. It slacks readily when exposed to air.

Several strip pits and a few mines are working in this area. Much prospecting has been done, and a quantity of lignite has been mined. All parts of the field are easily reached by a railroad and because of this more development is expected.

Little Sheep Mountain Coal Field

This field, 24 to 30 miles wide, extends westward 60 miles from Terry, and is bounded on the southeast by the Yellowstone River. In all, it covers an area of 1440 square miles. A ten mile strip of bad lands lies on the west, south, and eastern sides of the area, the remainder of the area being flat broad stream valleys for the most part. Yellowstone River is the main drainage system for the area.

The oldest rocks exposed in the area belong to the Lance formation, and are overlain by Lebo shale and upper
formations of the Fort Union group.

The rocks for the most part lie nearly horizontal, but have a small general dip to the east. Faults are uncommon. Cross-bedding in the Lebo shale is quite pronounced in this area.

The coal is in thin impure beds in the Lebo shale, and thick and fairly pure beds in the upper formation of the Fort Union. It is on the boundary between lignite and sub-bituminous with a woody structure and black color. The beds are often lenticular, but many are quite persistent, one of which was traced for 18 miles. Practically all the outcrops have been burned.

Considering any bed over 30 inches thick as workable, it has been estimated that there are 1,409,557,900 tons of coal with 1,189,833,380 tons recoverable. Most of this is found in the upper formation of the Fort Union group.

Miles City Coal Field

The Miles City coal field lies along Yellowstone River in the northern part of Custer County about 90 miles west of North Dakota, and covers an area of about 1000 square miles.

The area is drained by Yellowstone River, Tongue River, and Powder River, along with many creeks. The total relief of the area is 900 feet, river bottoms, river terraces, badlands, and plateaus making a rugged terrane.

All the exposed rocks are of Tertiary age except for unimportant alluvium and Lance strata in Yellowstone River.
valley, and all belong to the Fort Union group, 900 feet of which is exposed. Drill holes show the total thickness of the formation in this area to be about 1400 feet.

The strata lie nearly horizontal except where they have been disturbed by surface influences. No important faults and only a very few small local faults are present.

Coal beds are found throughout the entire section of Fort Union rocks exposed, but most of them are too thin or too impure to be of economic importance. There is a distinct change in the character of the coal from the lower to the upper beds. The lower beds are black and brittle and show little woody texture. This coal is classed as subbituminous. The upper beds are lignite which is dark brown, tough, woody, and of uniform purity. There are two workable horizons with an estimated 780,080,000 tons of coal or lignite.

Several small mines in the area have operated, their market being Miles City. However, not much future development is expected.

Terry Lignite Field

The Terry lignite field is in the eastern part of Montana immediately east of the Miles City field, and in the same general region as the Baker, Glendive, and Custer fields. It covers an area of about 1500 square miles.

The stratigraphy is much the same for this field as for the others in this region, the oldest rocks exposed belonging to the Pierre shale which is overlain by 700 feet
of Lance formation. Above this is the Fort Union group of which about 400 feet is exposed in the field.

The structure of the field is bordered on the east by the pronounced anticline which extends from Yellowstone River near the mouth of Cedar Creek southeast for 70 miles into the Dakotas.

The lowest coal occurs in the Lance in beds averaging 20 inches in thickness, beds of greater thickness being uncommon. In the Fort Union is a persistent bed 30 inches or more thick, and other beds of less importance are present. All beds are lenticular, but some may be traced for several miles. The upper beds of the series are obscured in outcrop by clinker. The coal is lignite grading into subbituminous.

There has been no extensive development work and but little prospecting in this field to date. For this reason its future cannot be foretold, but it will probably never be very important.

Baker Lignite Field

The Baker field is in the eastern part of Montana in Fallon County south of the Glendive field and east of the Terry field. It is part of the Great Plains region with local diversity in topography. Yellowstone River provides the chief drainage of the region.

The oldest exposed formation in this area is the Pierre shale which is Cretaceous in age. Its exposed thickness is about 200 feet, plus or minus, in this region. Above this
is the Colgate sandstone which has a thickness of 90 feet. It is considered part of the Lance formation which is also present. The uppermost formation, excluding Recent alluvium, is the Fort Union of which 300 feet is exposed in this area.

The structure is similar to that of the fields near to or adjacent to this one. The main feature is a pronounced anticline (Baker-Glendive anticline) which extends from Yellowstone River near the mouth of Cedar Creek southeast for 70 miles into the Dakotas. This structure has been proven to be favorable for the accumulation of oil and gas.

The lignite beds are found in the upper Lance and the Fort Union formations. In general the lignite is brown in color and has a woody texture. In the Lance the beds, which are three feet or more in thickness, occur in two zones, one near the top of the formation and the other about 100 feet lower. There are several thin beds between these zones but they are unimportant. The beds are extremely variable in thickness, extent, and grade. Another zone of lignite occurs in the Fort Union about 100 feet above the Lance. In general this lignite is better than that of the Lance, and this is especially true in the northern part of the field. In all parts of the Fort Union the coal occurs in small detached areas because of erosion, and all of the thicker beds are burned into a clinker at outcrops.

There is practically no development in this field, all mining being confined to local strip pits used by farmers to supply domestic needs. It is estimated that there are
1,596,054,000 short tons of lignite in beds three feet or more in thickness in this area. Three feet is considered the lower mineable limit for this grade of lignite. In all beds in the area the tonnage has been estimated at 2,394,071,000 short tons.

Mizpah Coal Field

The Mizpah coal field, along Mizpah Creek about 25 miles southeast of Miles City, comprises an area of 850 square miles. It is bounded on the east by Powder River, on the west by Pumkin Creek, on the north by the Miles City coal field, and the south by the primary base line of Montana. Relief in the field is moderate.

The oldest rocks in the area are of Tertiary age belonging to the uppermost part of the Lance formation. These beds have been described by Parker\* as follows: "Somber-colored siltstones, shales, and clays, and lesser amount of buff sandstones, buff shales, and thin lenticular coal beds and beds of carbonaceous shale. ---- The beds are more sandy in the southern part of the field. They are equivalent to the Lebo shale member of the Fort Union formation, the Tullock member of the Lance formation of neighboring regions, and the upper part of the Hell Creek member of the Lance formation as mapped in the Rosebud field. The basal 100 feet of the Tongue River member of the Fort Union formation ------ is also included in this unit." Above these

somber colored beds is 350 feet of the Tongue River formation of the Fort Union, and this in turn is capped by gravels and alluvium.

The structure of the area is simple, most of the strata lying with a very low dip (10 feet per mile). There are some small folds in the area but these are relatively unimportant.

The coal of the Mizpah field is lignite with a woody texture. It is tough when fresh but slacks rapidly when exposed to air. The lower part of the Lance is barren of coal beds, but there are numerous lenticular beds of coal, none of which exceed six feet in thickness, in the upper somber-colored beds. The Tongue River formation contains thick persistent beds of coal, but they are limited to the small area of the member that remains uneroded in this field. The estimated tonnage of the reserves of this field amount to 1,366,900,000 tons.

Ekalaka Field

This field is located in the southeastern part of Montana, and covers an area of more than 3000 square miles. It is part of the northern Great Plains with the topography consisting of wide surfaces of low relief traversed by broad river valleys of the Powder and Little Missouri rivers. Some bad lands are present in the area.

The oldest exposed rocks are in the Colorado group. Above this is the Pierre shale, and then the Lance formation,
consisting of two members, the Hell Creek and the Ludlow lignitic member. The Lance in turn is overlain by the Fort Union group (Tongue River formation) which is not prominent in the area. Above the Fort Union is an unconformity on which the White River formation of Oligocene age was laid down, and this formation in turn is followed by an unconformity and the Arikaree (?) formation. Pliocene gravel and alluvium lie unconformably on these sediments.

Regarding attitude of strata Bauer states that "The dominant structural features of this field are the north end of the Black Hills uplift, the parallel fold of the Cedar Creek or Baker-Glendive anticline, and the intervening broad, shallow syncline, in which minor anticlines and synclines are present."

Lignite is found in the Lance and Fort Union formations only in the northeastern part of the area and chiefly in the Ludlow lignitic member of the Lance. Chemically and physically the lignite is the same as that found in other fields in eastern Montana and the Dakotas.

Development to date has been very slight, and not much is expected in the future due to lack of railroads in the area and the character of coal beds.

Broadus Lignite Field

The Broadus lignite field is in Powder River County near Broadus in the southeastern part of Montana. It extends along Powder River for 30 or 40 miles both north and south.

*Bauer, C. M.; U.S.G.S. Bull. 751, p. 247.*
of Broadus. Southward beyond Moorhead the field connects with the Powder River Basin country of Wyoming, and it extends westward into the uplands. The Powder River has cut a deep valley through the area, and this valley is the main topographic feature. Tributaries of the Powder River have cut canyon-like valleys. Maximum relief is between 500 and 1000 feet.

The oldest rocks exposed belong to the upper Lance, but the formation is barren of coal. Stratigraphically above the Lance is the Lebo shale which is also barren of coal. The Lebo shale is along the lower slopes until about 15 miles south of Broadus where it goes under the level of the Powder River. The coal beds are found in the Fort Union above the Lebo shale, between 100 and 500 feet above the base of the formation. At Broadus they are rather high up on the hill sides, but are nearly at river level near Moorhead.

The area lies on the east side of the Powder River Basin where the strata rise on the flank of the Black Hills uplift. The beds near Broadus dip from 100 to 300 feet per mile westward into the Powder River Basin.

There are several beds of coal, all in the Fort Union, and in some places thicknesses of 15 to 20 feet have been noted. The coal is a black lignite similar to other Montana lignites and it slacks readily on exposure.

There is little development in this field, mainly because of the lack of railroad transportation, the closest
railroad being 60 miles away at Miles City. However, a small amount of the lignite is mined and used locally.

Southwestern Montana Districts

Several minor districts in southwestern Montana where coal has been found have been noted. The region includes approximately that portion of Montana west of the Continental Divide and south of the watershed between the Flathead River and Clark Fork. The principal drainage is the Clark Fork of the Colombia River. At least five-sixths of the area is mountainous with the rest gently sloping valley bottoms and bench lands.

Although impure coal occurs locally in intensely folded Cretaceous strata, more important strata, as far as the coal is concerned, is Tertiary in age, and is largely lacustrine in origin.

Pardee* in describing these strata states that "The Tertiary lake beds of this region were deposited subsequent to the epoch of great folding in the Rocky Mountains. Since their deposition, however, structural movement has folded the Tertiary rocks into broad, shallow synclines or monoclines, and in places the beds have been faulted. In general the lake beds near the margins of the valleys dip moderately toward the center of the basin, but this dip decreases until near the middle of the basins the beds are practically horizontal."

All of the coal is subbituminous in grade, and commonly banded dull to bright black. It is dense and brittle, and has a semi-conchoidal fracture and a black streak. There is not enough data about the coal to estimate the tonnage. Future development will probably be restricted to local pits which will supply domestic fuel.
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**Chart Showing Geologic Distribution of Montana**

**Explanation**
- Thickness of beds:
  - Less than 5 feet
  - 5 to 10 feet
  - 10 to 20 feet
  - 20 to 30 feet

**Type of Coal**
- Lignite
- Subbituminous
- Bituminous
- Coking

341 to 906 U.S. tons per acre
PLAN A-B: NICKNESS OF BEDS

LESS THAN 5 FEET
5 TO 10 FEET
10 TO 20 FEET
20 TO 30 FEET

TYPE OF COAL
LIGNITE
SUBBITUMINOUS
BITUMINOUS
COKING

INDEX MAP

LOGIC AND GEOGRAPHIC
OF MONTANA COAL