SOUTH DAKOTA

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 3

A PRELIMINARY REPORT OF THE COAL RESOURCES OF SOUTH DAKOTA

By

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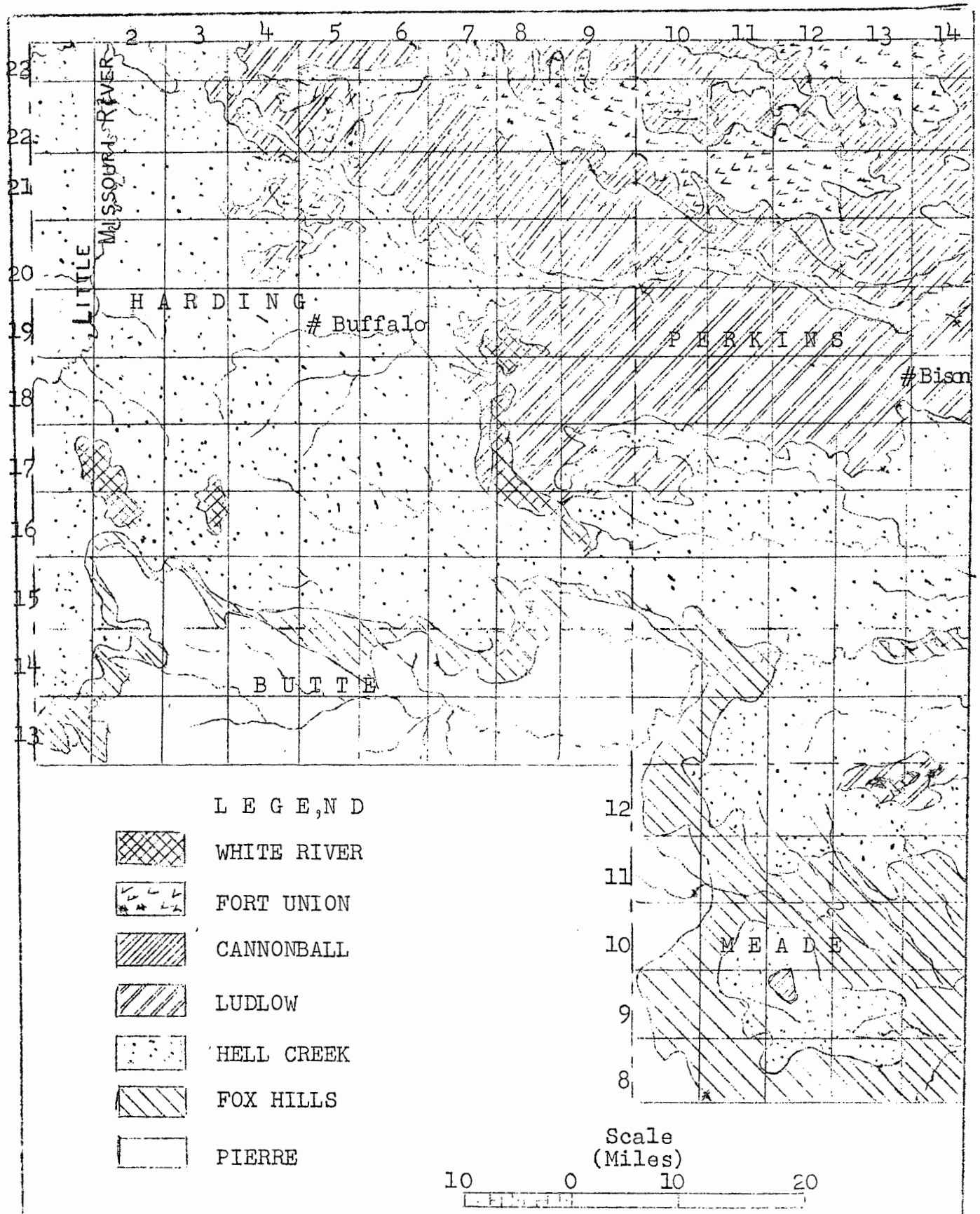
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LITTLE MISSOURI RIVER
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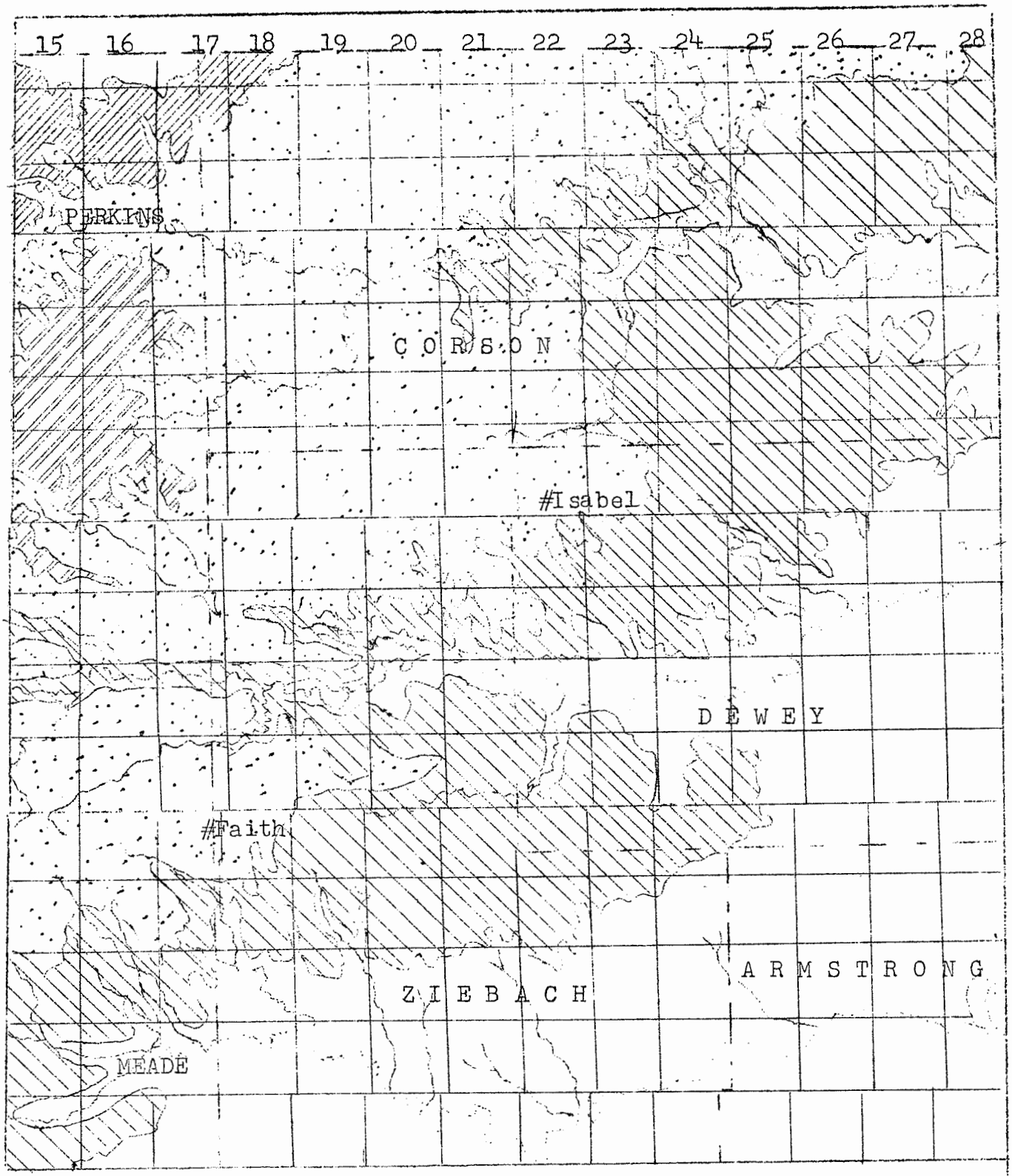

GEOLOGICAL MAP OF

NORTHWESTERN SOUTH DAKOTA

Showing Coal Bearing and Associated Formations

SOUTH DAKOTA GEOLOGICAL AND NATURAL
HISTORY SURVEY

E.P.Rothrock, State Geologist Compiled by Walter V. Searight

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A PRELIMINARY REPORT ON THE COAL RESOURCES OF SOUTH DAKOTA

By

Walter V. Searight

I N T R O D U C T I O N

General Statement. The coal which underlies portions of northwestern South Dakota not only constitutes the most important native fuel of the immediate region, but at the present time it is the only native fuel of the state known to be capable of commercial development. Since the settlement of the northwestern counties of the state, coal mined in the South Dakota field has supplied practically all of the local fuel demand. The known coal resources of the field so much exceed local needs that greater development in the future is to be expected and encouraged. Future development should be based on knowledge of the location, size and thickness of coal beds, together with accurate information on the local conditions, bearing on coal recovery. This report is prepared to present a description of the geography, geology, and development of the South Dakota coal field in a preliminary way which will serve as a basis for future development and investigations, and to acquaint interested persons with the important factors bearing on the present and future development of the field.

Previous Geologic Work. Reconnaissance of the South Dakota coal field began in 1854 with the expedition of F. V. Hayden[1], who crossed the eastern and southern parts of the area and recognized the Fox Hills formation and the overlying beds now known as the Lance. Two decades later N. H. Winchell[2], geologist with Capt. Ludlow's expedition which crossed western Butte County east of the Little Missouri River, noted the large area underlain by the coal bearing formations which he grouped together under the term "Laramie". He also recognized formations older and younger than the rocks now known as Lance and Fort Union. In the summer of 1884 a

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1/ Darton, N. H., Geology and Underground Waters of South Dakota, U. S. Geol. Survey, Water Supply Paper 227, p. 27,1909.

2/ Report of a Reconnaissance of the Black Hills of Dakota, by William Ludlow, U. S. A., Washington, 1875.

party of geologists headed by Bailey Willis[3] travelled from Mandan, Dakota, (now in North Dakota) to the Standing Rock Agency, thence to the mouth of the Moreau River and proceeding westward crossed to the north side of the Moreau River, 21½ miles west of the Missouri, probably the present location of Promise, in Dewey County. From this point the party ascended the divide between the Moreau and Grand Rivers where, 60 miles west of Missouri River, thin beds of impure coal were found. Although no workable coal beds were found in the area between Rabbit Butte and Firesteel Creek by this expedition, the formations were correctly assigned to Pierre, Fox Hills, and "Laramie", the later formation, however, including brackish water beds now regarded as Fox Hills in age. Subsequently in 1890, 1895, 1902, reconnaissance was carried on by J. E. Todd, and recorded in bulletins of the South Dakota Geological Survey.[4] In 1909 studies of the Standing Rock and Cheyenne River, Indian Reservation in the eastern portion of the coal field,[5] and in 1911 and 1912 the northwestern portion of the field was investigated by Winchester, Hares, Lloyd and Parks of the United States Geological Survey.[6] Several papers, including bulletins and circulars, dealing with the geology of the South Dakota coal field have been published by the South Dakota Geological and Natural History Survey, mostly in connection with oil investigations of the area.

Acknowledgements. The writer is indebted to the previous investigators whose reports and maps have been freely consulted. The cooperation of mine owners, operators and residents of the field, during the field season of 1929 is greatly appreciated. Mr. Harold Norbeck served efficiently as assistant in the field.

Field Work. The field season of 1929 was spent mostly in coal investigations. The producing mines and many abandoned mines and natural outcrops were investigated.

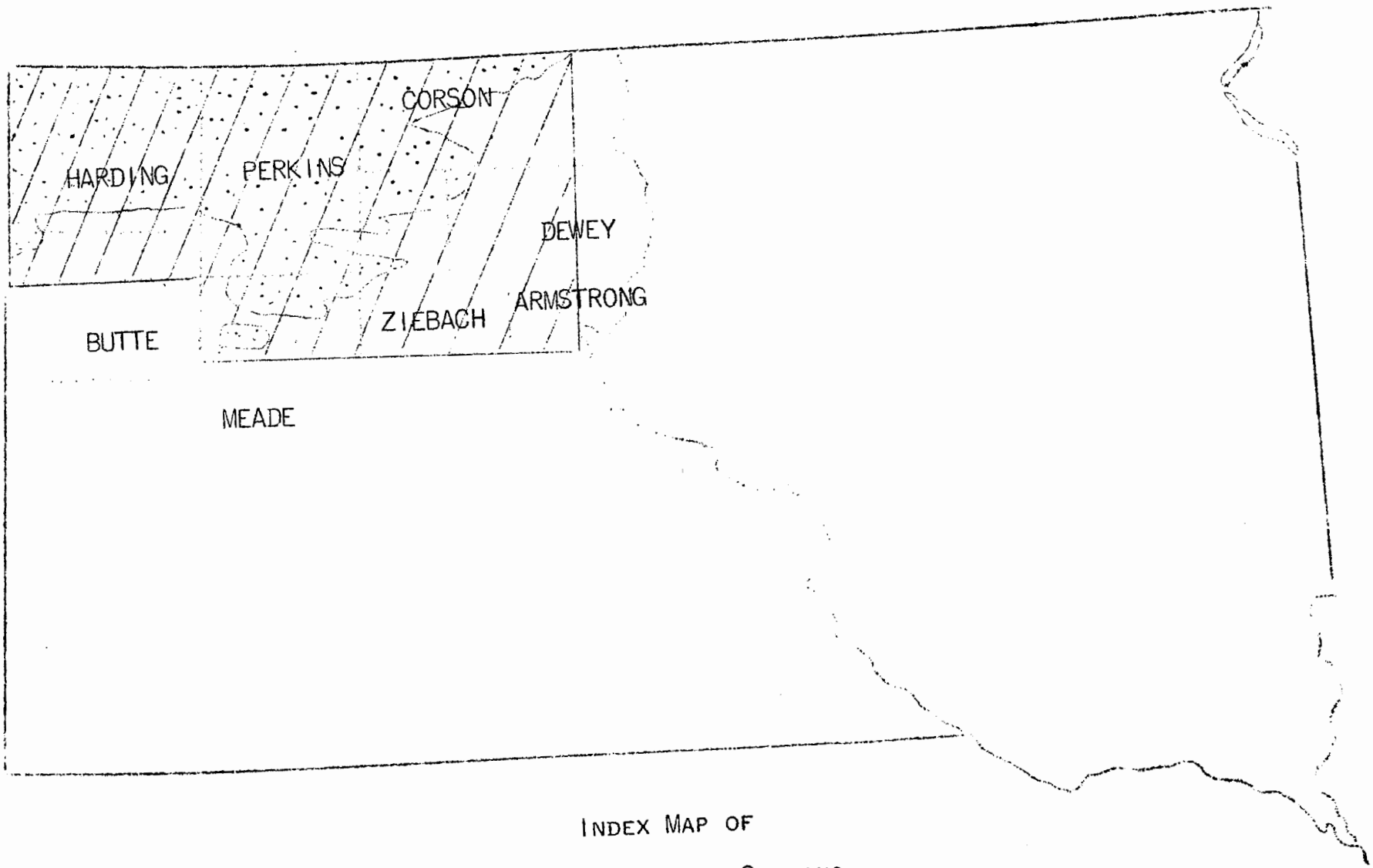
3/ Willis, Bailey, The Lignites of the Great Sioux Reservation, U. S. Geol. Survey, Bull. No. 21, pp. 339-348, and plates I-IV, 1885.

4/ Todd, J. E., Geology of South Dakota, South Dakota Geol. Survey Bull. 1, 1894.
Todd, J. E., First and Second Biennial Reports, South Dakota Geol. Survey Bull. 2, pp. 41-68, 1898.
Todd, J. E., Preliminary report on the Geology of the Northwest-Central portion of South Dakota, South Dakota Geol. Survey Bull. 4, pp. 13-76 and 193-207, 1908.

5/ Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian Reservations; U. S. Geol. Survey Bull. 575, 1914.

6/ Winchester, D. E., and others, The Lignite Field of Northwestern South Dakota, U. S. Geol. Survey Bull. 607, 1916.

PLATE I



INDEX MAP OF

SOUTH DAKOTA SHOWING
LOCATION OF THE COAL FIELD

L O C A T I O N A N D A R E A

The South Dakota coal field lies entirely west of Missouri River and north of Cheyenne River. The index map, Plate I, shows the location of the area treated in this report and the approximate boundaries of the coal bearing formations. The width of the area shown on the map is approximately 163 miles from west to east, and the length from north to south, 92 miles. The total area, therefore, is approximately 13,436 square miles of which 7630 miles are underlain by coal bearing formations. In many places, however, these formations are not productive.

The geological map (Plate II) includes all of the coal bearing rocks of the state with the exception of small outliers, such as Castle Rock Butte and Deers Ears in Butte County, and certain beds of Lower Cretaceous age south of the Black Hills in the vicinity of Edgemont, Fall River County. The beds outside of the coal field as mapped appear not to contain coal beds of commercial importance. The greater portion of the South Dakota coal field thus lies in Harding, Perkins and Corson Counties, although it extends beyond these into Dewey, Ziebach, and Meade Counties.

P H Y S I O G R A P H Y A N D G E O G R A P H Y

Topography. The South Dakota coal field lies entirely in the Great Plains province, northeast of the Black Hills uplift, and west of the glaciated prairies. The area slopes in a general way from the western boundary of the state, which is at an approximate average elevation of 3200 feet above sea level, to 2000 feet along the eastern boundary. The eastward slope of the region, however, approaches flatness only here and there, being broken by elevations consisting of many buttes and mesas, and by depressions, most of which are stream valleys. Locally buttes rise 400 feet or more above the plains. The valleys are cut as much as 500 feet below the general slope of the plains. The surface thus varies from extremely flat to extremely rough topography, the extreme examples of which are badlands bordering the area underlain by coal bearing formations and surrounding the Slim Buttes.

Surface features are due largely to the nature and attitude of the underlying rocks, which have been eroded under conditions of fairly low precipitation. The topography resulting from varying degrees of resistance to erosion is shown in the accompanying diagram (Plate III). Soft shales, such

as the Pierre formation, under erosion become gently rounded hills, excepting near large valleys where relatively steep bluffs are formed and where slump or landslide topography is very common. The sandy beds are reflected in flattish areas which in the last stages of erosion leave sandstone capped buttes and mesas which are common in many parts of the coal field. The most prominent mesas are the Slim Buttes, Cave Hills, Short Pine Hills, Lodgepole Buttes, and Fox Ridge. Prominent buttes resulting from the resistance of capping horizontal sandstone beds are Thunder Butte, Anarchist Butte, Taylor Butte, and many others. Badland topography resulting from erosion of clays under semi-arid conditions are well developed in many places, especially where clay formations near large valleys, such as Little Missouri, Grand, and Moreau Rivers. Topography of badland character is developed also to a high degree around the Slim Buttes in Harding County.

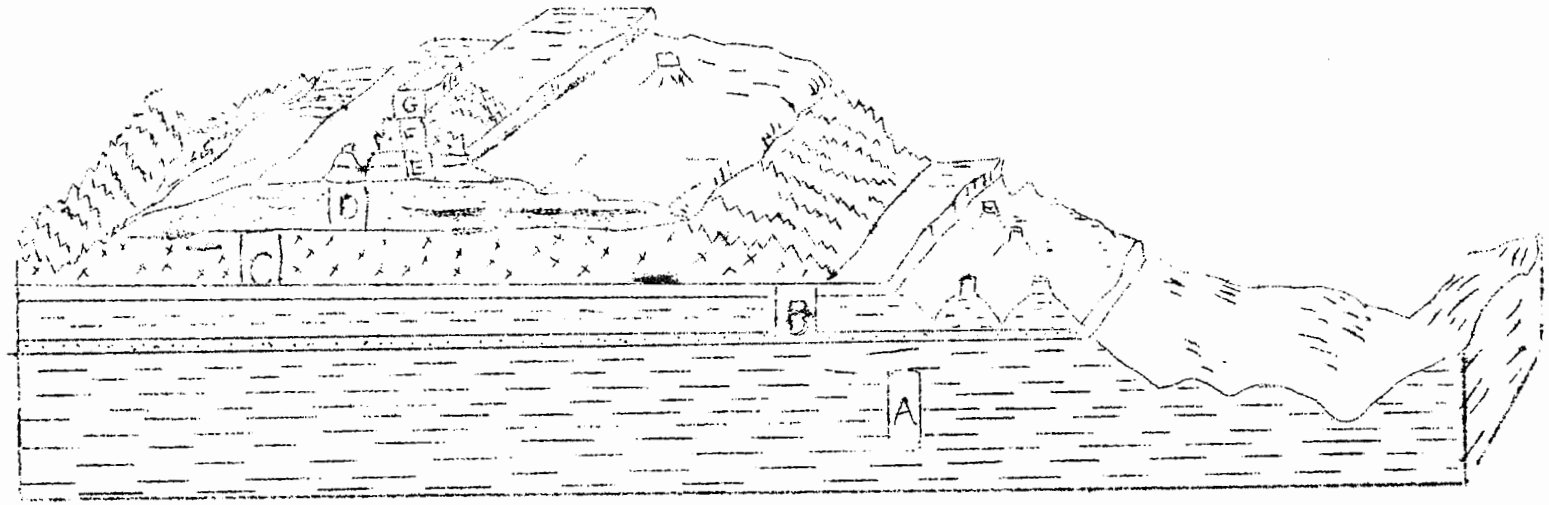
The highest point in the area is approximately 3500 feet above sea level on the Slim Buttes in Harding County, and the lowest approximately 1410 feet. The maximum relief of the area is, therefore, somewhat less than 2100 feet.

Drainage. Drainage is entirely to Missouri River mostly by two major streams, Grand and Moreau Rivers, and their tributaries. South of the divide between Moreau and Cheyenne Rivers drainage is by tributaries to Cheyenne River, the largest tributary being Sulphur (Cherry) Creek. Most of Harding County is drained by Little Missouri River and its tributaries, and the southwestern part of the area by the upper portions of tributaries to Belle Fourche River. The extreme northeastern part of the area shown on the map is drained by Oak Creek which is tributary to Missouri River.

Culture. Towns and villages within the coal field are for the most part small and scattered, except along railways where there are numerous small railway towns. The most important railway towns, are, Dupree, Eagle Butte, Faith, Isabel, Lemmon, McIntosh, McLaughlin, and Timber Lake. The most important inland towns are Bison, Buffalo, and Camp Crook.

Railways. Portions of the eastern part of the coal field are served by railways, but the greater part of the area is without railways facilities. Railways, for the most part, are on the Grand-Cannonball River divide, the Grand-Moreau divide, and the Moreau-Cheyenne River divide.

The main lines of the Chicago, Milwaukee, St. Paul and Pacific Railroad connects Mobridge with Lemmon across northern Corson and Perkins counties. This line passes into North Dakota west of Thunder Hawk, but bends southward through Lemmon and White Butte. From White Butte, South Dakota to Hettinger, North Dakota, however, this railway is near the South Dakota



BLOCK DIAGRAM

TO SHOW TOPOGRAPHY PRODUCED ON FORMATIONS OF NORTH-WESTERN SOUTH DAKOTA

A-PIERRE BLOCK
B-FOX HILLS
C-HELL CREEK
D-LUDLOW
G-ARIKAREE(?)
E-FORT UNION
F-WHITE RIVER

boundary. A branch of the Chicago, Milwaukee, St. Paul and Pacific Railroad crosses southeastern Corson county and northern Dewey County, through Trail City, and terminates at Isabel in Dewey County. A southern branch from Trail City crosses southeastern Dewey and Ziebach Counties to Faith in the northeastern corner of Meade County.

Highways and Roads. The coal field is supplied with numerous highways and roads, the most important of which have been improved by grading and surfacing.

Several east-west highways cross the coal field. Federal Highway 212, a gravel and earth grade passes across the southern part of Dewey, Ziebach, and northern Meade Counties. A state highway, No. 18, in part gravel surfaced and entirely graded crosses the area from Mobridge east of the area through Camp Crook across southeastern Corson, northwestern Dewey, northern Ziebach, and central Perkins and Harding counties. A gravel and earth grade, Federal Highway 12, connects Mobridge and White Butte crossing eastern and northern Corson and northeastern Perkins Counties.

North-south roads serve as connections between the main east and west highways. Federal Highway 85 crosses Harding County from Bowman, North Dakota to Belle Fourche, and connects with State Highway 79 to Newell and Sturgis. Most of these roads are graded and complete grading is contemplated. A gravelled road, State Highway 73, connects Lemmon with State Highway 18. A partially graded road connects Faith with State Highway 18, and State Highway 24, south and west to Sturgis, is improved. State Highway 65 is an improved earth road from Isabel to Dupree to McIntosh on Federal Highway 12, and State Highway 63 is graded between Timber Lake on State Highway 18, south to Federal Highway 212, and continues southward to Federal Highway 14, south of the coal field, which passes through Pierre and Rapid City.

Other more or less improved roads serve local areas. Most of the roads and highways of the coal field even where not gravel surfaced are in good condition in dry weather, but some, especially those crossing the "gumbo" of the weathered Pierre formation become very poor or impassible in wet weather.

ROCK FORMATIONS

Introductory statement. The rocks of the South Dakota coal field are known from outcrops at the surface and from their occurrence in mines and in deep wells. Although the rocks which contain coal are of first importance, those which are known to be without coal are also important in coal studies.

Formations without coal occur in close associations with coal bearing rocks so that a knowledge of both coal bearing and non-coal bearing rocks is desirable in order that the owner, operator, and miner may confine his investigations to rocks of probable value. Since the position of coal bearing rocks in the succession of the coal field is known a knowledge of any formation becomes of value because it is an indicator of the position of coal bearing beds. All of the formations near the surface in the South Dakota coal field are thus of importance in coal investigations.

The rocks outcropping in the South Dakota coal field consist of beds of rock laid bed on bed and formation on formation in orderly arrangement. The oldest of those which outcrop at the surface are to be found mostly at low elevations where their surface exposures are due to the removal of overlying younger beds by stream erosion. The rocks at the surface range from those oldest rocks known as Cretaceous up through younger rocks known as Tertiary to the youngest rocks of the Recent Period. Although beds older than Cretaceous are known to occur below the area at considerable depth only those rocks of Cretaceous and later periods contain coal in important quantities. In the pages which follow the coal bearing rocks are described together with the associated Cretaceous and younger beds.

All of these rocks known from artificial excavations and natural outcrops consist of sedimentary rocks due to the transportation and deposition of pre-existing rocks. Some beds are composed of mineral matter sufficiently compressed and cemented as to form consolidated rock, whereas others, such as clays, sands, and gravels, are more or less loosely cemented. All of these materials, whatever the degree of consolidation, are called rocks by the geologist and will be so described in this report.

Rocks are commonly divided by the geologist into beds, members, formations, and systems according to the order of their natural arrangement. The rocks of the coal area are shown in the table of succession or columnar section which follows arranged with the Cretaceous below up to the Pleistocene and Recent at the top as they occur in nature. The map (Plate II) shows the surface distribution of these rocks.

CRETACEOUS SYSTEM

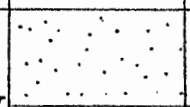
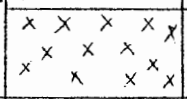
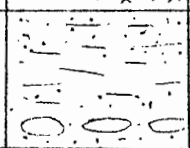
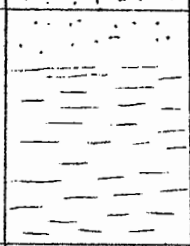
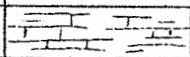
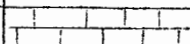
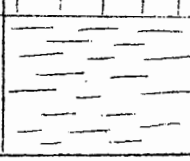
COLORADO SERIES

Under northwestern South Dakota as elsewhere in the state the Colorado Series consists of four formations, which in their order from the base up are the Graneros, Greenhorn, Carlile, and Niobrara. These are separated partly by their lithologic differences but in many places almost wholly by their fossil content.

GENERALIZED COLUMNAR SECTION

OF

NORTHWESTERN SOUTH DAKOTA

System	Series	Formation and Number	Columnar Section	General Character	Thickness
Tertiary	Miocene ?	Arikaree?		Gray and greenish fine grained sandstone	235-265
		Unconformity			
	Oligocene	White River		Light colored clays & coarse sandstone	113-188
		Unconformity			
Cretaceous? Tertiary?	Laramie Eocene?	Fort Union		Sandstone and shale Contains coal	300
		Ludlow Cannonball		Cannonball, sandstone & shale marine Ludlow, sandstone, shale & clay, contains coal	0-225
		Hell Creek		Somber colored clays & argillaceous sandstone, contains coal	425
Cretaceous	Montana	Fox Hills		Sandstone and shale with limestone concretions	25-350
		Pierre		Dark gray to black shale with concretions in various horizons	1440
	Colorado	Niobrara		Shale and chalk	175-300
		Carlile		Bluish gray shale with limestone concretions	465-700
		Greenhorn		Calcareous shale & chalk	65-70
		Graneros		Dark gray to black shale contains limestone in thin beds and in concretions	260±

Graneros Formation

The Graneros formation is known to underlie the coal field from drilling in the southeastern part of the coal field, and from outcrops southwest of the coal field, near the Black Hills. This formation is composed predominantly of shale, commonly dark bluish gray or black in color with which limestone concretions and thin beds of limestone are interbedded in nearly all areas of outcrop in South Dakota. In a drilling near Worthless (Irish) Creek in northern Ziebach County the greater portion of the shale penetrated was more or less chalky. The approximate average thickness of the formation in the northern Black Hills is 1000 feet. In the Worthless (Irish) Creek Well the formation was penetrated to a depth of 260 feet.

Greenhorn Formation

The Greenhorn formation consists of dark gray chalky and calcareous shale with which some thin beds of limestone are interbedded. A bed of argillaceous limestone lies at or near the base of the formation in a well drilling on Worthless (Irish) Creek in northern Ziebach County. In outcrops near the Black Hills and in southeastern South Dakota as elsewhere the Greenhorn is characterized by the profuse occurrence of the fossil Inoceramus labiatus. The thickness of the formation is 65 to 70 feet.

Carlile Formation

The Carlile formation is a succession of beds of bluish gray shale interbedded with which are a few thin beds of impure limestone. In areas of outcrop limestone concretions are to be found at various horizons. The formation is characterized wherever it has been identified by the guide fossil Prionotropsis woolgari and by other fossils. Near the Black Hills southwest of the coal field the maximum thickness of the Carlile is estimated at 700 feet, whereas in the southeastern portion of the coal field in the drilling on Worthless Creek 465 feet of shale beds are assigned to the formation by the writer.

Niobrara Formation

The Niobrara, which is the uppermost formation of the Colorado series consists of gray shale beds which are more or less chalky throughout and which are impure chalk in part, at

least in some places in the area. Chalk beds underlying the coal field are thin, whereas, to the southeast of the area the chalky character is increasingly pronounced so that in the southeastern part of the state chalk is the chief constituent of the rock. In the outcrop outside the coal field the cup shaped oyster, Ostrea congesta, is the guide fossil, but underground as in the coal field microscopic fossils, such as Textularia, Globigenira, and Orbulina are the most useful guide fossils. The thickness of the formation as indicated by drilling in the southeastern part of the coal field approximated 300 feet although the formation may be thin as 175 feet as suggested in the outcrop area southwest of the coal area.

MONTANA SERIES

The Montana series lies on the Niobrara formation of the Colorado series and below the Hell Creek member of the Lance. In the South Dakota coal field the series has been divided into two formations, a lowermost, the Pierre, and an uppermost, the Fox Hills. The contact between the two formations is one of gradation, represented in many places by beds whose character, both lithologic and faunal, partakes of the character of both the underlying and the overlying formations.

Pierre Formation

The Pierre Formation is the oldest formation outcropping in the South Dakota coal field and here only the upper part is known at the surface, the complete thickness being known only from deep drilling.

Distribution. The Pierre is the surface formation in the southwestern portion of the area along North Fork and South Fork of Moreau River and their tributaries, along the headwaters of Sulphur (Cherry) Creek and along tributaries which drain into Cheyenne River. It also has extensive surface distribution along the lower part of the valley of Sulphur (Cherry) Creek, along the valley of Cheyenne and Moreau Rivers and to a lesser extent along the valley of Grand River in the northeastern part of the area.

Stratigraphic Details. The Pierre formation in the coal field as elsewhere is remarkably uniform both laterally and vertically. Considerable evidence, however, suggests that, in many places, the formation is divisible on lithologic and faunal grounds into two members, a thick lower member and a relatively thin upper member. In the eastern part of the area lithologic differentiation is most apparent, whereas in the

southwest fossils furnish the most satisfactory criteria for differentiation of the members. The following table of succession is typical of the Pierre formation.

Section of Pierre formation penetrated in Worthless (Irish) Creek well in S. E. ¼, Sec. 17, T. 15 N., R. 20 E., compiled from log,[1] and from log in the Survey files.

	Thickness--Feet
Upper Pierre	
Shale, silty shale, and sandstone, dominantly bluish gray; with most silty portions light shades which weather to brown and buff. Greenish sandstone abundant in the 75 foot interval which lies at about the base of the member. Contains both Pierre and Fox Hills fossils, Transition beds- - - - - - - - - - - - - - - - - -	196
Lower Pierre	
Shale, dark gray, in part calcareous, in part silty- -	277
Shale, light bluish gray with some beds of fine greenish gray silt or sandstone in upper 13 ft., in some parts calcareous, in others dolomitic- -	438
Shale, light bluish gray, material probably bentonite, abundant throughout, dominantly bentonite-like material in lower 200 feet- - - - - - -	395
Shale, very dark, bituminous, in part somewhat dolomitic- - - - - - - - - - - - - - - - - - - -	140
Total Thickness -	1446

The lower member of the Pierre in the outcrop consists of soft dark gray to nearly black shale on which gentle slopes are produced by erosion. Weathering reduces the shale to the "gumbo" which is very sticky and tenacious when wet. On drying a network of cracks bounding roughly polygonal areas is characteristic of the weathered shale.

The upper member of the Pierre in many places is distinctly silty or sandy in texture and grades without definite lithologic boundaries into the lower member of the Pierre below, and the Fox Hills formation above. This portion of the formation where most typically developed is buff and brown in the outcrop.

1/ Russell, W. L., S. Dak., Geol. and Nat. Hist. Survey, Circular 18, 1925.

Thickness. The Pierre is the thickest formation of the coal field. The lower member, the entire thickness which is known within the area only from deep drilling in the southeast part of the area, is approximately 1240 feet thick, and the upper approximately 200 feet thick. The total thickness of the formation southwest of the area is believed to be about 1440 feet[1], which is in agreement with the thickness of 1440 feet penetrated in the Worthless (Irish) Creek well.

Fox Hills Formation

Definition. The Fox Hills is the formation lying above the Pierre and below the Hell Creek member of the Lance. It differs from the underlying upper Pierre in the greater predominance of yellow, buff, and brown colors in outcrop in its sandy texture, and in the fossils which it contains.

Distribution. The Fox Hills outcrops in a band varying from a maximum width of nearly forty miles in the eastern part of the area to a minimum width of a fraction of a mile in southern Harding County. As shown by the map (Plate II) the formation lies everywhere between the outcrop area of the Pierre and that of the Hell Creek member of the Lance. The surface distribution is greatest in eastern Corson County across Dewey and northern Ziebach, and in northern Meade County. The formation has limited distribution, however, in southern Perkins County along Moreau River and as a narrow band from a fraction of a mile to six miles wide in southwestern Perkins County and southern Harding and northern Butte Counties.

Stratigraphic relations. The Fox Hills formation grades lithologically downward into the Pierre in such a manner that the boundary is a zone rather than a definite line of demarkation. Similarly, fossils regarded as Fox Hills forms are to be found in many places associated with Pierre fossils in beds here assigned to the upper member of the Pierre.

Above, the Fox Hills-Hell Creek boundary appears to be one of gradation from the marine Fox Hills through brackish water sandstone of the Fox Hills into the basal Hell Creek. The upper limit of brackish water beds or their equivalent is here inclosed and chosen arbitrarily as the top of the Fox Hills. In many places a hard sandstone which is, locally, very fossiliferous, lies at the top of the formation and marks the boundary with the Hell Creek.

Lithologic Details. In the type area from which the formation was named in the divide between Moreau and Cheyenne Rivers in Dewey and Ziebach Counties, the Fox Hills consists of basal sandstone member overlain in many places by sandstone beds. In some places these are filled with brackish water fossils, in other plant remains consisting mostly of leaves

1/ Darton, N. H., U. S. Geological Survey, Geol. Atlas, Belle Fourche, Folio No. 164, P. 5, 1909.

are abundant and elsewhere similar beds occupying their stratigraphic position are entirely barren of fossils.

The lower member of the Fox Hills consists of fine sandstone of yellow to brown color which contains one or more zones of limestone concretions, which are composed of limestone, which when fresh is dark blue gray, but brown when weathered. Characteristic marine fossils are exceedingly abundant in many of these concretions, but others are barren.

Overlying the lower member in the typical locality is a succession of beds mostly of shale and silt but with, here and there, beds of fine sand. These beds are commonly brown in color. Since they commonly form flattish areas of Fox Hills outcrop area, good exposures of this member are rare.

The uppermost Fox Hills consists of beds of sandstone of greenish gray color which are absent in some places but elsewhere are conspicuously developed as more or less indurated sandstone which forms butte caps along the boundary of the Fox Hills outcrop area nearest the Hell Creek member of the Lance. In many places these sandstones are cross bedded and in most places are massive. One or more beds of oyster shells (Ostrea glabra) are to be found in many places with other characteristic brackish water shells. In other places fossil leaves of deciduous trees are found abundantly in greenish gray sandstone of similar character lying in the stratigraphic position of the sandstones previously described. Elsewhere greenish gray and buff sandstone, in many places unindurated but in others firmly cemented at the position of the beds of the upper Fox Hills appears to be entirely without fossils. Position and lithology suggest that these sandstones are contemporaneous deposits.

In southern Harding and northern Butte Counties sandstone, mostly yellow and brown in color is poorly exposed at the position of the Fox Hills between the Pierre and Hell Creek. Characteristic marine fossils of the basal Fox Hills have not been found by the Survey nor has the brackish water fauna of the upper Fox Hills been noted. The formation is much thinner than in the remainder of the area outcrop.

Thickness. The Fox Hills varies in thickness between 25 and 350 feet. Greatest thicknesses are developed in the eastern portion of the outcrop area since in many places in southern Harding and Butte Counties the formation appears to be only 25 feet in thickness.

CRETACEOUS ? -- TERTIARY ?

LANCE

The Lance Formation of the South Dakota coal field includes three members; the Hell Creek, the basal member which

lies on the Fox Hills; the Ludlow member, which lies below the Fort Union, and the marine Cannonball member which occupies the position of the upper part of the Ludlow, and which lies below the Fort Union in northern Perkins county and adjacent portions of Harding and Corson Counties. The formation includes the lower part of the Laramie as described in the early reports of the Survey.[1]

Hell Creek Member

Distribution. The Hell Creek member has the widest distribution at and below the surface of the coal bearing formations of the coal field. (Plate II). This member forms the surface rock over much of Harding County, most of the southern half of Perkins County, and most of the western half of Corson County. From these larger main portions of the outcrop area it extends into Butte, Meade, Ziebach, and Dewey Counties. Outliers occur in many places, some outside the map (Plate II), but these are not known to contain workable coal beds.

The outcrop area of the Hell Creek member includes approximately 5300 square miles in South Dakota. An additional area of approximately 2300 square miles is covered by younger formations.

Surface expression. The Hell Creek member of the Lance erodes into badlands near large valleys, whereas in situations remote from streams gently rounded hills and ridges are formed. As a badland former the Hell Creek resembles the well known White River beds of the Big Badlands along White River. The topography thus produced consists of a complex of small valleys and gullies with steeply sloping walls separated by sharp or pinnacled divides.

Lithologic character. The Hell Creek member of the Lance consists of clay shale, fine sandstone and some coal. Outcrops of the rocks display gray, brown and some yellowish gray, shades of gray from light to dark being characteristic. Thus the beds nearly everywhere exhibit dull or somber hues.

Beds are lenticular and can rarely be traced for more than a mile. In most cases single beds are traceable for much lesser distances. Beds vary in thickness from a fraction of an inch up to 15 feet or more. Contacts between beds are sharp in many places, but elsewhere intergradation between beds is common. Thus sandstone with clay filled interstices grades upward into silicious clay, and laminated shales grade into clays which are without lamination. Here and there beds of limonite and hematite up to a foot in thickness are found interbedded with clays or shales.

1/ Todd, J. E., Geology of the Northwest-Central Portion of South Dakota, South Dakota Geological Survey Bull. No. 4, pp. 32-37, 1908.

Coal beds in common with the other beds of the member are lenticular and underlie small areas. In some places two or more beds of coal occur in the same section, whereas elsewhere coal is absent throughout the section. In the eastern portion of the outcrop area of the Hell Creek, coal beds appear to be largely confined to the lower two hundred feet of the member, but near the Slim Buttes the upper part of the member contains coal.

Fossils. Fossils of the Hell Creek consist of dinosaurian remains of which the most common are bones of Triceratops. In the eastern portion of the South Dakota coal field, dinosaur bones appear to be confined to the lower part of the Hell Creek member, whereas in Harding County they are found in the upper part. Fresh water pelecypods similar to the "clams" found in the recent streams occur also in these beds in certain localities.

Thickness. The thickness of the Hell Creek member is approximately 425 feet in Harding and Perkins Counties.[1] The thickness of the Lance in the eastern part of the area is estimated to 700 feet[2], but in this thickness an unknown thickness of beds of the Ludlow member of the Lance is included.

Correlation. The Hell Creek beds of South Dakota are lithologically similar to the Hell Creek member of the Lance as developed in eastern Montana, and are correlated with them by the Survey. They are the Triceratops beds of some writers and the Lower Lance or "somber beds" of others.

Ludlow Member

Definition. The Ludlow member of the Lance is a succession of beds dominantly of sandy character. These lie on the Hell Creek member and conformably below the Fort Union in parts of northern Harding County. In northern Perkins County, however, it lies below the Cannonball member of the Lance.

Distribution and area. The beds of the Ludlow member are the surface rocks over fairly wide areas in northwestern Harding County, and in north central Perkins County (Plate II). Outliers also lie outside the main outcrop areas. The largest of these are the South Cave Hills in north central Harding County and Fox Ridge near the center of the north boundary of

1./ Winchester, D. C., and others, The Lignite Field of Northwestern South Dakota, U. S. Geol. Survey Bull. 629, p. 19, 1916.

2./ Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian Reservation, U. S. Geol. Survey Bull. 575, p. 17, 1914.

Meade County. Coal bearing beds near Stoneville in Meade County, provisionally mapped as Ludlow, are the southernmost outcrop of the member, if further investigations justify this correlation. The distribution of the Ludlow at the surface is approximately 1200 square miles but the member is covered by younger beds over an additional area of considerable size. On the map (Plate II) the boundary between the Ludlow and Cannonball members is approximate, since exact boundaries between the two members have not been mapped.

Lithologic character. The Ludlow member of the Lance consists of sandstone, sandy shale, clay and shales, with coal. The member is commonly of light shades of yellow and buff with some brown and gray beds. It differs from the underlying Hell Creek in the greater proportion of sand with correspondingly lesser amounts of clay and in the more vivid colors which are in fairly sharp contrast with the somber hues of the Hell Creek. Sandstone beds are commonly friable, thick, and in many cases massive. Locally, however, these beds are firmly cemented. Flat, spherical, ovoid, or loglike concretions of cemented sandstone occur in many places in different parts of the formation. These concretions are in many cases extremely large, one exposed in the mine in SW¼, Sec. 31, T. 18 N., R. 12 E., having been observed to be from 8 to 11 inches thick and 80 feet long and having been reported more than 40 feet across.

As in the Hell Creek member coal beds are lenticular but may be traced in some cases a few miles. Coal beds while commonly thin reach observed thicknesses of 14 feet 6 inches and reported thickness of 16 feet.

The following tables of succession are representative of the rocks of the Ludlow member:

Section of basal Ludlow in Sundermeyer mine in the N.E.¼, N.W.¼, Sec. 20, T. 17 N., R. 17 E.

		Feet
9.	Sandstone, upper 20 feet poorly exposed, gray to yellow buff, ripplemarked and crossbedded in upper 20 feet. Upper 15 feet contains elongate concretions of five ripplemarked, sand cemented with calcium carbonate, concretions up to 50 feet in length- -	36
8.	Shale and sandstone in alternating beds, upper 1 foot ripplemarked, sand 1 in. to 1 ft. 3 in. thick-	3 5/6
7.	Shale, light gray, horizontally laminated, fairly hard- -	4 ¼
6.	Coal, black, much bright- - - - - - - - - - - - - - -	2 ½
5.	Clay shales, medium gray, horizontally bedded, contains fossil stems and sticks - - - - - - - - - - - -	1
4.	Coal, black, contains pyrite masses to 6 inches in diameter, upper ½ foot impure - - - - - - - - - - - -	2 1/3
3.	Shale, medium to dark gray, thin bedded, fossil sticks and heavy present- - - - - - - - - - - - - - - -	¼-2/3

2.	Coal, black, horizontally bedded, vertically jointed, fairly hard.	1
1.	Clay, drab brown, fine in texture, contains rootlets	1+
	Total thickness exposed. . .	51

Section of the Ludlow member in the Giannonatti mine in the N.E.¼, Sec. 29, T. 21 N., R. 7 E.

		Feet
3.	Sandstone, hard, ripplemarked.	4
2.	Sandstone, buff and yellow, friable, crossbedded and massive in lower part 13 feet micaceous in upper part. Elongate concretions up to 8 inches thick, 8 feet wide, 12 feet long in base.	71
1.	Coal, lignitic, black and brown interbedded, brown beds tough and woody, lower part not exposed	9+
	Total thickness exposed. . .	84

Section of upper part of the Ludlow member exposed in, below, and above the Hilton mine, new opening of 1929, in the N.W.¼, Sec. 6, T. 20 N., R. 5 E.

		Feet
Fort Union		
19.	Sandstone, reddish brown, buff, where fresh, "rim rock".	20+
18.	Covered, probably friable sandstone	40
Lance		
Ludlow member		
17.	Sandstone, light gray to yellow buff, fine; Large log-like concretions 20 feet above the base.	20
16.	Coal, black, brittle above, tough below . . .	3
15.	Clay shale, light gray, laminated, some glance coal.	3¼
14.	Coal, impure.	1/3
13.	Clay shale, light gray.	5/6
12.	Coal, impure.	1/4
11.	Clay, medium gray, sticky when wet, exposed .	1
10.	Covered	38
9.	Coal, black	1½
8.	Clay, gray.	½
7.	Coal, black and brown, mostly black, woody. .	7½
6.	Clay, gray.	½
5.	Coal, black	1
4.	Clay, gray.	1/8
3.	Coal, black	½
2.	Clay, gray.	5/12
1.	Coal, black	1
	Total	119

Thickness. The Ludlow member of the Lance ranges be-

tween 300 and 350 feet in thickness in the vicinity of Ludlow Harding County.[1] East and northeast of this, the type locality of the Ludlow, the member becomes thinner, so that southeast of Lemmon, Perkins County, the member appears to be very thin or absent and its position is occupied by the Cannonball member of the Lance.

Fossils. The Ludlow member contains plant fossils in many places, but is without dinosaurian remains, so far as known. Plant leaves, mostly those of deciduous trees, are common. Evergreens, among which Sequoia is most abundant, also occur. The plants are, for the most part, of the same kinds as those found in the younger Fort Union.

Cannonball Member

Definition. The Cannonball member of the Lance is a succession of beds containing marine fossils. At the eastern boundary of the outcrop area in northwestern Corson and northeastern Perkins Counties the member occupies the position of the Ludlow, but thins toward the west in such a manner that it occupies the position of the upper portion of the Ludlow member in northwestern Perkins County. It apparently pinches out in northern Harding County. Thus in the eastern part of the outcrop area, it is the formation which occupies the position of the Ludlow, but in the west the position is of the Cannonball is occupied by the Ludlow.

Distribution. The surface distribution of the Cannonball member of the Lance is chiefly in northern Perkins County. Outcrops, however, are to be found in the extreme northeastern part of Harding County and have been observed by the writer in the extreme northwestern part of Corson County also. The outcrop area on the map (Plate II) shows approximately the general distribution of the member in South Dakota.

Lithologic character. The beds of the Cannonball member of the Lance are composed of sandstone, shale and some thin lenticular beds of limestone. Like the Ludlow, the member is commonly yellow or brown. The Cannonball is thus very similar in lithologic composition and color to the Ludlow of which it appears to be the marine equivalent.

The lithologic succession is well shown in the following table:[2]

Generalized section in the vicinity of Bloom, South Dakota, T. 23 N., R. 9 E. (After Winchester and others.)

1./ Winchester, D. E., and others, The Lignite Field of Northwestern South Dakota, U. S. Geol. Survey, Bull. 627, P. 20, 1916.

2./ Winchester, D. E., and others, op. cit., p. 23, 1916.

Lance		Feet
Cannonball		
9.	Sandstone, brown and yellow, fine grained, thin bedded, interbedded with lenses of compact bluish-gray limestone.	30
8.	Sandstone, dark gray, calcareous, marine .	10
Ludlow		
7.	Shale.	1
6.	Lignite.	2
Cannonball		
5.	Shale and sandstone, interbedded; sandstone in lower part light brown, medium fine grained, micaceous, marine.	40
Ludlow		
4.	Lignite.	1
3.	Shale.	4
2.	Lignite.	2¼
1.	Shale.	
	Thickness	90¼

Fossils. The Cannonball member of the Lance contains marine invertebrate fossils of a fauna which strongly resembles that of the Fox Hills. The chief dissimilarity of the Cannonball fauna with that of the Fox Hills lies in the lack, in the Cannonball, of cephalopods of the Discoscaphites group and of the genus Sphenodiscus.

Relations and age. The Cannonball is considered to be the equivalent of portions of the continental Ludlow. The member appears to be conformable with Hell Creek, Ludlow and the Fort Union. The fauna of the Cannonball member is Cretaceous in aspect, whereas the flora of the Hell Creek, the contemporaneous Ludlow, and the overlying Fort Union are of Eocene aspect. Since, however, the Cannonball sea seems to have been a readvance of the sea which retreated in Fox Hills time, to a not far distant region, and since no great erosion period is recorded in the succession from the Fox Hills to the uppermost Fort Union, the writer is inclined to the view that the Cannonball is Cretaceous in age.

CRETACEOUS? TERTIARY? SYSTEM

Fort Union Formation

Definition. The Fort Union is a succession of beds lying stratigraphically above the Ludlow in many places. Elsewhere the formation lies on the Cannonball member of the Lance. In South Dakota it is the youngest formation lying below the White River beds.

Distribution. The Fort Union formation has limited distribution in South Dakota, being the surface formation over parts of northern Perkins County, northeastern Harding County, and possibly a square mile or more in northwestern Corson County (Plate II). Outside of these larger areas of outcrops as shown on the geologic map (Plate II), the formation caps the North Cave Hills and the South Cave Hills which are mesas in northern Harding County.

The total distribution of the Fort Union in the South Dakota coal field is approximately 314 square miles, a small part of which is covered by younger deposits.

Lithologic details. The Fort Union in the South Dakota coal field consists of sandstones, silty sandstones, silts, shales, clays, and at least two coal beds. Included in the formation are also some calcareous and some quartzitic rocks. Most of the beds are more or less sandy and quartzose and occur in various shades of yellow, drab, and brown, but beds of shale and clay in shades of gray from light to dark are common.

The lowermost portion of the formation consists of sandstone which is friable in the eastern part of the outcrop area. In the western part of the outcrop area these basal sandstones are firmly cemented to form the massive "rim rock" or "cap rock" which caps North and South Cave Hills in northern Harding County. In the North Cave Hills mesas the basal sandstone is 200 feet or more in thickness. It consists of a lower friable buff or yellowish brown member 75 to 100 feet thick which is overlain by reddish brown, massive sandstones about 135 feet thick.[1]

Overlying the basal sandstone of the Fort Union is a succession of beds composed mostly of shale but containing also some interbedded sandstone, clay, and coal. Most of the shales are gray, commonly of light shades but dark gray, brown, and black carbonaceous beds of shale occur. Shale and sandstones commonly weather yellow and brown so that these are the predominating colors in natural exposures.

Included in this succession are one or more beds of quartzite of unusual character. This quartzite when casually observed appears to be chert of drab or drab gray color. Magnification, however, shows it to be composed of very small grains of quartz which are closely cemented with silica. Impressions of roots, or of roots, stems, and branches are to be seen as tubular openings varying in size from a small fraction of an inch up to three or four inches in diameter. The quartzite occurs in place at the top of the Cave Hills, in the Lodgepole Buttes,[2]

1./Winchester, and others, The Lignite Field of Northwestern South Dakota, U. S. Geol. Survey, Bull. 627, pp. 27-28, 1916.
2./Winchester, and others, The Lignite Field of Northwestern South Dakota, U. S. Geol. Survey, Bull. 627, p. 30, 1916.

southeast of Ellingson, and in the Buttes south of White Butte post office in T. 22 N., R. 14 E. The rock occurs in many places as scattered boulders, often in great profusion, not only in the Fort Union outcrop area but also on Ludlow, Cannonball, Hell Creek, Fox Hills and Pierre. In fact boulders of this quartzite have been observed here and there over the coal field from the top of Cave Hills to Missouri River. Evidence suggests that some of the boulders of this quartzite west of Missouri River were derived from the area east of the river during the Pleistocene.

The scattered quartzite boulders are for the most part residual and probably indicate the former extent of the Fort Union in South Dakota. Observations by Todd, however, suggest that a part of them may have been derived from the White River formation.[1]

The occurrence of a bed of quartzite in place is shown in the table of succession which follows:

Section showing quartzite and associated beds exposed below, in and above the Mickelson mine in the N.E.¼, Sec. 15, T. 22 N., R. 14 E.

		Thickness--Feet
Fort Union		
7.	Sandstone, buff, friable.	25
6.	Shale, light gray	2
5.	Coal, black	3/4
4.	Coal, bony, impure.	1½
3.	Coal, black	4
2.	Clay, hard, gray.	2
1.	Quartzite, drab, root impressions abundant. .	2
	Total.	37¼

Lying above the shale succession is a member composed of massive yellow and brown sandstone beds which form the cap of many buttes in Twps. 21 and 22 N., Range 12 E. It also caps Anarchist Butte in Sec. 34, T. 22 N., R. 9 E. The upper sandstone member of the Fort Union is probably about 100 feet.[2]

The tables of succession which follow were made by the Winchester Survey,[3] and are typical of the Fort Union above the basal sandstone. The first includes the upper portion of the shale member, whereas the latter includes also the upper sandstone member in the upper four beds.

Section of the Fort Union, in Sec. 36, T. 22 N., R. 9 E.

1./ Todd, J. E., Geology of South Dakota; South Dakota Geol. Survey, Bull. 2, pp. 60-61, 1898.
2./ Winchester, and others, The Lignite Field of Northwestern South Dakota, U.S. Geol. Survey, Bull. 627, p. 30, 1916.
3./ Winchester, and others, op. cit., p. 29, 1916.

		Feet
22.	Sandstone, gray to yellow, friable, with indurated concretions.	10
21.	Shale, grayish, weathers yellow; slightly sandy; thin limonite layers; mica flakes.	22
20.	Shale, brown	5/6
19.	Shale, gray to brownish.	4
18.	Shale, brown	1
17.	Shale, grayish, weathers yellow; slightly sandy, thin limonite layers; mica flakes.	6½
16.	Shale, brown to black, carbonaceous.	2
15.	Shale, grayish, slightly sandy; thin limonite layers; mica flakes.	10 3/4
14.	Shale, brown and gray.	3
13.	Sandstone, brown, very fine grained, containing clay, with some carbonaceous matter, rather hard	½
12.	Shale, gray to brown	5½
11.	Shale, brown, very sandy, containing charcoal. . . .	2
10.	Shale, gray laminated, sandy, partly carbonaceous. .	8
9.	Shale, brown to dark, fissile.	2 1/3
8.	Shale, gray to yellowish	5
7.	Shale, brown to black, fissile	2
6.	Shale, gray to yellowish, with thin streaks of limonite, thinly laminated, grading into underlying shale	8½
5.	Shale, black, brittle, fissile, carbonaceous	1 1/3
4.	Iron, probably bog iron, containing wood	½
3.	Lignite, dirty	1/3
2.	Sandstone, brown, bituminous	2+
1.	Covered.	

Section of Fort Union exposed in Anarchist Butte in Sec. 34, T. 22 N., R. 9 E.

		Feet
15.	Sandstone, brown, coarse, forming cap of hill. . . .	51½
14.	Shale, chocolate-colored, with coal smut	1
13.	Sandstone, orange to cream-colored, fine grained, with some limonite crusts.	20
12.	Sandstone, yellow to buff, fine grained, with many limonite layers 4 or 5 inches in thickness; 8 feet above base is a more resistant layer, which forms a shelf in many places	18
11.	Shale, chocolate-colored, with some lignite.	1½
10.	Clay, drab	4
9.	Quartzite; under surface of layer rather stalactitic	1½
8.	Clay, lilac-colored.	3
7.	Shale, black, fissile.	1
6.	Shale, chocolate-colored, fissile.	20
5.	Lignite, weathered	1
4.	Shale, chocolate-colored	5
3.	Lignite, weathered	2
2.	Shale, chocolate-colored	½
1.	Covered.	
	Total	130

Thickness. The Fort Union is approximately 300 feet thick in the Lodgepole Buttes,1 where the thickest exposures occur.

Stratigraphic relations. The Fort Union lies in apparent conformity on older formations.

Fossils. The fossils which have been found in the Fort Union are leaves of deciduous trees and fragments of evergreens.

TERTIARY

OLIGOCENE

White River Formation

Definition and relations. The White River formation is a succession of clay and coarse sandstone beds. In the coal field it lies unconformably on beds varying in age from Hell Creek to Fort Union. The White River underlies the Miocene(?) Arikaree(?) unconformity.

Distribution. The beds of the White River occur in the area as isolated outliers. The most notable of these are the Slim Buttes, the Short Pine Hills in Harding County and Fox Ridge in northern Meade County.

Lithologic Details. The White River formation in this region consists of light colored clays and fine sandstone, coarse sandstone and conglomerate, thin limestones and chalcedonic concretions and joint filling. As in the White River Badlands, the White River clays are mostly white or very light gray or pink, sandy clays. A member composed of coarse sandstone or fine gravel occurs in many places at or near the base of the formation. This member is made up chiefly of somewhat worn quartz grains, but it also contains worn cleavage fragments of feldspar as well as chert. Pebbles of quartz, feldspar, silicified wood and chert occur in many places.

The following table of succession compiled from a description by a former member of the Survey shows the lithologic succession in the Slim Buttes:[2]

Generalized section of White River beds in the Slim Buttes, Harding County.

	Feet
4. Clay, pink, nodular, bedding obscure-.	60

1./ Winchester, and others, The Lignite of Northwestern South Dakota; U. S. Geological Survey Bull. 627, p. 27, 1916.
2./ Toepelman, W. C., The Possibilities of Oil in Eastern Harding County, South Dakota Geol. and Nat. Hist. Survey, Circular 12, p. 6, 1923.

3.	Clay, white; sandy clay and coarse gray sands, alternating in beds from few inches to 2 feet thick, partly consolidated.	40-100
2.	Clay, plastic, gray to olive green.	3-8
1.	Sandstone, white, contains numerous rounded fragments of feldspar	10-20
	Total.	113-188

Topographic expression. The White River formation of this region, as in the type locality along White River, is a badland former. Intricate dendritic gully systems, separated by sharp crested and pinnacled divides are characteristic erosion features of the formation here as elsewhere.

MIOCENE(?)

Arikaree Formation

The Arikaree(?) formation consists chiefly of massive sandstone which is the cliff former at the top of the Slim Buttes and of the East and West Short Pine Hills. Interbedded with the sandstone are lenses or beds of conglomerate which occur in the lower part of the formation.

The following table of succession of the Arikaree(?) is compiled from descriptions by a former member of the Survey.[1]

Generalized section of the Arikaree(?) of Harding County, South Dakota.

		Feet
4.	Sandstone, gray to light green, fine grained, several thin beds of white material resembling volcanic ash near top.	100
3.	Sandstone and shale, gray to light green, cross-bedded on small scale, bedding somewhat obscure.	50
2.	Sandstone, white to pink, very fine, laminations very thin.	80-90
1.	Conglomerate, sand, and clay	5-25
	Total	235-265

Stratigraphic relations. The Arikaree(?) lies unconformably on the White River and in T. 18 N., R. 8 E. It lies on the Ludlow. The formation is thus unconformable on all older beds.

1./ Toepelman, W. C., op. cit., p. 7-8, 1926.

COAL AND ITS OCCURRENCE IN SOUTH DAKOTA

General Statement. The coal field of South Dakota is a part of the Northern Great Plains Coal province, as defined by the United States Geological Survey. The South Dakota field forms a southeastern extension of the Fort Union region which is the easternmost region of the Northern Great Plains province and which lies in North Dakota, Montana, and South Dakota. This region furnishes the major part of the local fuel supply, and also supplies fuel to a considerable surrounding area.

The coal of this field occurs in quantities which can be profitably mined in only two formations, the Lance and the Fort Union although evidence suggests that coal bearing rocks here assigned to the Ludlow member of the Lance are Fox Hills in age.[1] In the preceding pages these coal bearing formations have been described together with associated formations and their distribution is shown on the geologic map. (Plate II)

Coal beds of the South Dakota field, as in other fields, are lenticular. The thickest portions of the beds are near the center and they pinch out at the borders. The coal beds of the Hell Creek member of the Lance and some beds of the Ludlow member of the Lance are of lenticular character since they cannot be traced over large areas. Most of the Ludlow and the Fort Union coal beds are of considerably wider extent but these, the latter in particular, have been dissected by stream erosion so that lenses originally covering many square miles have been cut into smaller patches.

South Dakota coals have most of their physical characters in common, although important differences occur. They range in color from dark brown to black. The streak (color of the powdered coal) of all, however, is brown. The coal of most, if not all of the beds is made up of three kinds, dull coal, glance coal, and fusian or mineral charcoal. The dull coal is commonly dark brown, although in many places it is black. Furthermore, dull coal has but little gloss or luster. In some beds the dull coal is tough and fibrous. Glance coal is black, has a high luster and is commonly more or less brittle. In most cases glance coal appears, in cross or vertical section of the coal beds, as small lenses of bright coal between laminations composed of dull coal. In sections parallel with the bedding it appears in elongate masses, which, in favorable situations, assume the outline of much compressed branches and trunks of trees. Indeed, in many cases the grain of the wood is sufficiently well preserved in glance coal of South Dakota beds to be evident to the naked eye. Fusian, or mineral charcoal, has the appearance of fragments of charcoal, distributed irregularly on the bedding planes. This variety

1./ Wilson, R. A., Oil and Gas Possibilities in Northeastern Meade County, S. Dak. Geol. and Nat. Hist. Survey, Circ.23, p.5-6,1925.

has not been a common constituent of coal in this field, although it is abundant in some beds.

Some coal beds also contain thin beds of black, more or less highly carbonaceous clay or shale which is very similar to coal. This material is locally known as "black jack" and corresponds to "Bone" or "Bony coal" of eastern coal fields.

When fresh the coal contains from 29.8 to more than 46.5 percent of moisture, and averages about 37.56 per cent. Drying in air reduced the moisture content from these percentages to a minimum of 2.3, a maximum of 18.8, or an average of 9.5 per cent.[1]

Moisture content of South Dakota coal is most important since coal shipped or hauled as mined contains more than one third water, which is valueless as fuel. Drying before transportation as shown by the above figures, greatly reduces this excess water content. Loss of water in drying, however, causes the coal to shrink very considerably with the result that it checks and breaks into small pieces, in some cases to fine material incorrectly called "slack coal". Moisture content of the South Dakota coal and the behavior of the coal due to loss of water on drying are among the most important problems in the utilization of this fuel.

CHEMICAL COMPOSITION

The chemical composition furnishes most reliable data for comparison of relative coal values. All coals are composed of volatile matter, carbon, moisture, and ash with subordinate amounts of sulphur. Analyses of coal are commonly given in one or more of four forms which are as follows: A, as received at the analytical laboratory; B, air dried under uniform conditions; C, dry or water free; and D, water and ash free. In the first form, A, the chemical composition of the coal is represented as it comes from the mine with all the water present. Moisture content, however, varies with topographic position of the coal bed, situation of the bed with relation to ground water surface, position of the coal with respect to drainage, nearness of the coal to the surface, length of time coal is exposed to the air and character of overlying and underlying beds. Analyses of different samples of coal "as received" thus vary greatly because of water content. Form B represents the chemical constituents of the coal after excess water has been removed under a temperature somewhat above normal. Composition of coals shown in this form are best suited for comparison. However, considerable variation in moisture content after air drying enters into this form of analyses, and is due to weathering treatment at the mine, and the manner of shipping. Forms C and D are computed from the other two. The former represents the coal with all water removed, and the latter presumably the coal

1./ Percentages given are computed from tables 1, 2, 3, on pp. 26, 27, 28, 29, and 30.

substance with water and ash, the most important impurity, removed.

Each of the forms of analysis may be represented as either proximate or ultimate analysis or it may be represented by both of these. Amount of chemical constituents in the sample is commonly represented in per cent. The most important of these elements in coal are carbon, oxygen, hydrogen, nitrogen and sulphur. In the proximate analysis the elements are combined to represent as closely as possible the moisture, volatile matter, fixed carbon, and ash.

Heating value is commonly expressed in British Thermal Units per pound of coal.[1] The heating value, however, is sometimes given in calories.[2]

In the tables which follow analyses of coals from the South Dakota field are given. These tables show proximate and ultimate analyses together with the heating value. Wherever possible, the analyses are given four forms as described above. The analyses are grouped in three tables, those of Table 1 being of Hell Creek coals, Table 2 of Ludlow coals, and Table 3 of Fort Union coals. In Table 3, two analyses of Fort Union coals from North Dakota have been added for completeness. Table 4, includes for comparison analyses of coals from nearby fields and from other regions.

1./ One British Thermal Unit (B.T.U.) is the amount of heat required to raise one pound of water through one degree Fahrenheit at 60°.

2./ A calorie is the amount of heat required to raise one gram of water through one degree centigrade.

ANALYSES OF HELL CREEK COALS[1] TABLE I

Name and Location[2]	Analyst[3]	Form of Analyses[4]	Proximate: Moisture	Proximate: Volatile Matter	Proximate: Fixed Carbon	Proximate: Ash	Ultimate: Sulphur	Ultimate: Hydrogen	Ultimate: Carbon	Ultimate: Nitrogen	Ultimate: Oxygen	Heating Values: Calories	Heating Values: B.T.U.
1	M	A	34.96	30.33	28.80	5.91	0.30	.....	.....	.....	.....	.....	7,144
		C	.....	46.63	44.29	9.08	0.46	.....	.....	.....	.....	.....	10,984
2	M	A	34.90	27.57	32.69	4.84	0.30	.....	.....	.....	.....	.....	7,101
		C	.....	42.35	50.22	7.43	0.46	.....	.....	.....	.....	.....	10,907
3	M	A	34.98	25.34	31.15	8.53	0.31	.....	.....	.....	.....	.....	6,854
		C	.....	38.97	47.91	13.12	0.48	.....	.....	.....	.....	.....	10,541
4	G	A	42.5	23.2	25.3	9.00	1.16	7.07	35.22	0.62	46.93	3,310	5,950
		B	17.7	33.2	36.2	12.88	1.66	5.83	50.39	0.88	26.86	4,735	8,520
		C	....	40.4	44.0	15.64	2.02	4.08	61.21	1.08	15.97	5,750	10,350
		D	....	47.8	52.2	.....	2.39	4.84	72.56	1.28	18.93	6,815	12,270
Averages of Hell Creek Coals		A	36.83	26.61	29.48	7.07	0.52	.....	.....	.....	.....	.....	6,762
		C	.....	42.09	46.60	11.32	0.85	.....	.....	.....	.....	.....	10,695
Averages of Lower Hell Creek Coals		A	34.95	27.75	30.88	6.43	0.30	.....	.....	.....	.....	.....	7,033
		C	.....	42.65	47.47	9.88	0.47	.....	.....	.....	.....	.....	10,811

1./ Analyses 1, w, and 3 are of samples of lower Hell Creek coals.

2./ Name and location: (1) Robbins Mine near Isabel; (2) Kennedy mine near Gopher; (3) Anderson mine near Gopher; (4) Phillips mine, Strool, S.W.$\frac{1}{4}$, Sec. 7, T. 17 N., R. 11 E.

3./ Analyst: M--Charles Bentley, from Connolly, J. R. and O'Harra, C. C., The Mineral Wealth of the Black Hills, South Dakota School of Mines Bull. No. 16, p. 396, 1929.

4./ G--E. E. Somermeier and A. C. Fieldner, U. S. Geol. Survey and U. S. Bureau of Mines.

4./ Form of Analyses: (A)--As received; (B)--Air dried; (C)--Moisture; (D)--Moisture and ash free.

ANALYSES OF LUDLOW COALS

TABLE 2

Name and Location[1]	Analyst[2]	Form of Analyses[3]	Proximate				Ultimate					Heating Values	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Hydrogen	Nitrogen	Carbon	Oxygen	Calories	B.T.U.
1	M	A	32.98	28.41	29.10	9.51	1.31	....	....	.....	.....	.....	7,075
		C	.....	42.39	43.42	14.19	1.95	....	....	.....	.....	.....	10,555
2	G	A	39.2	24.7	27.8	8.35	2.22	6.60	.53	38.02	43.28	3,505	6,310
		B	17.8	33.3	37.6	11.28	3.00	5.02	.71	51.38	28.61	4,735	8,520
		C	.....	40.6	45.7	13.72	3.65	3.70	.87	62.49	15.57	5,760	10,370
		D	.....	47.2	52.8	.....	4.23	4.29	1.01	72.43	18.04	6,675	12,020
3	M	A	40.01	23.56	30.08	6.35	0.42	....	....	.....	.....	.....	6,150
		C	.....	39.27	50.14	10.59	0.70	....	....	.....	.....	.....	10,251
	B	A	31.2	27.1	31.0	10.7	2.4	5.9	.6	40.9	39.5	3,750	6,750
		B	11.9	34.8	39.6	13.7	3.0	4.5	.8	52.4	25.6	4,806	8,650
		C	.....	39.5	45.0	15.5	3.4	3.6	.9	59.4	17.2	5,450	9,810
		D	.....	46.7	53.3	.....	4.1	4.2	1.0	70.4	20.3	6,456	11,620
4	G	A	41.5	24.0	24.3	10.2	.55	....	....	.....	.....	3,140	5,650
		B	10.4	36.8	37.3	15.5	.84	....	....	.....	.....	4,810	8,650
		C	.....	41.0	41.6	17.4	.94	....	....	.....	.....	5,365	9,660
		D	.....	49.6	50.4	.....	1.14	....	....	.....	.....	6,495	11,690
	G	A	41.1	25.8	24.0	9.1	1.14	....	....	.....	.....	2,955	5,320
		B	10.3	39.3	36.5	13.9	1.74	....	....	.....	.....	4,495	8,090
		C	.....	43.9	40.7	15.4	1.94	....	....	.....	.....	5,015	9,020
		D	.....	51.9	48.1	.....	2.30	....	....	.....	.....	5,930	10,680
5	G	A	34.7	27.2	29.0	9.1	.95	....	....	.....	.....	3,475	6,250
		B	11.1	37.1	39.4	12.4	1.29	....	....	.....	.....	4,735	8,520
		C	.....	41.7	44.4	13.9	1.46	....	....	.....	.....	5,325	9,580
		D	.....	48.3	51.7	.....	1.70	....	....	.....	.....	6,185	11,140
6	M	A	40.85	23.80	26.36	8.99	0.90	....	....	.....	.....	.....	5,791
		C	.....	40.23	44.57	15.20	1.53	....	....	.....	.....	.....	9,790
	B	A	44.4	24.0	19.7	11.9	0.7	6.70	0.40	28.50	51.80	2,467	4,440
		B	3.8	41.6	34.0	20.6	1.2	3.5	.7	49.4	24.6	4,267	7,680
		C	.....	43.2	35.4	21.4	1.3	3.2	.8	51.3	22.0	4,439	7,990
		D	.....	55.0	45.0	.....	1.6	4.0	1.0	65.3	28.1	5,644	10,160

TABLE 2 (CONTINUED)

Name and Location	Analyst	Form of Analyses	Proximate				Ultimate					Heating Values	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Hydrogen	Nitrogen	Carbon	Oxygen	Calories	B.T.U.
7	G	A	39.8	25.3	23.8	11.1	.96	...	...	....	....	3,045	5,480
		B	10.2	37.8	35.5	16.5	1.44	...	...	....	....	4,545	8,110
		C	....	42.0	39.6	18.4	1.59	...	...	....	....	5,060	9,110
		D	....	51.6	48.4	....	1.95	...	...	....	....	6,200	11,160
8	G	A	34.7	26.4	27.6	11.3	1.08	...	...	....	....	.....	.....
		B	18.8	32.9	34.4	13.3	1.34	...	...	....	....	.....	.....
		C	....	40.5	42.3	17.2	1.65	...	...	....	....	.....	.....
		D	....	48.8	51.2	....	1.99	...	...	....	....	.....	.....
9	B	A	38.0	24.4	25.5	12.1	1.0	6.3	.5	34.6	45.5	3,067	5,520
		B	12.9	34.3	35.8	17.0	1.4	4.4	.7	48.7	27.8	4,306	7,750
		C	....	39.4	41.1	19.5	1.6	3.4	.8	55.9	18.8	4,944	8,900
		D	....	48.9	51.1	....	2.0	4.2	1.0	69.4	23.4	6,144	11,060
10	B	A	37.1	27.2	24.3	11.4	.9	5.9	.5	33.2	48.1	2,789	5,020
		B	7.3	40.1	35.8	16.8	1.3	3.5	.7	49.0	28.7	4,117	7,410
		C	....	43.2	38.7	18.1	1.4	2.9	.8	52.8	24.0	4,439	7,990
		D	....	52.8	47.2	....	1.7	3.5	1.0	64.5	29.3	5,422	9,760
11	B	A	34.4	25.5	28.8	11.3	1.2	6.1	.5	37.6	43.3	3,367	6,060
		B	2.9	37.7	42.7	16.7	1.7	3.7	.8	55.7	21.4	4,978	8,960
		C	....	38.8	44.0	17.2	1.8	3.4	.8	57.3	19.5	5,128	9,230
		D	....	46.9	53.1	....	2.1	4.1	1.0	69.2	23.6	6,194	11,150
12	B	A	29.8	26.5	31.3	12.2	1.7	5.9	.6	40.8	38.6	3,767	6,780
		B	2.3	36.8	43.6	17.3	2.4	3.8	.8	56.8	18.9	5,239	9,430
		C	....	37.7	44.6	17.7	3.4	3.7	.8	58.1	17.3	5,361	9,650
		D	....	45.8	54.2	....	3.0	4.5	1.0	70.6	20.9	6,511	11,720
13	B	A	33.0	25.8	26.1	15.1	2.4	5.9	.5	35.2	40.9	3,228	5,810
		B	3.9	37.0	37.5	21.6	3.5	3.7	.8	50.5	19.9	4,633	8,340
		C	....	38.5	39.0	22.5	3.6	3.4	.8	52.6	17.1	4,822	8,680
		D	....	49.7	50.3	....	4.7	4.3	1.0	67.9	22.1	6,222	11,200

TABLE 2 (CONTINUED)

NAME AND LOCATION	ANALYST	FORM OF ANALYSES	PROXIMATE MOISTURE	PROXIMATE VOLATILE MATTER	PROXIMATE FIXED CARBON	PROXIMATE ASH	ULTIMATE SULPHUR	ULTIMATE HYDROGEN	ULTIMATE NITROGEN	ULTIMATE CARBON	ULTIMATE OXYGEN	HEATING VALUES CALORIES	HEATING VALUES B.T.U.
L14	B	A	40.5	25.5	22.8	11.2	1.6	6.8	.5	32.6	47.3	2,867	5,160
		B	3.0	41.6	37.2	18.2	2.6	3.7	.8	53.2	21.5	4,678	8,420
		C	....	42.9	38.3	18.8	2.7	3.5	.8	54.9	19.3	4,822	8,680
		D	....	52.9	47.1	....	3.4	4.3	1.0	67.6	23.7	5,939	10,690
15	B	A	40.7	24.4	22.2	12.7	1.7	6.3	.4	30.7	48.2	2,683	4,830
		B	6.2	38.5	35.3	20.0	2.7	3.5	.7	48.6	24.5	4,239	7,630
		C	....	41.1	37.6	21.3	2.9	3.0	.7	51.8	20.3	4,522	8,140
		D	....	52.2	47.8	....	3.7	3.9	.9	65.9	25.6	5,750	10,350
16	B	A	46.5	20.6	25.0	7.9	.7	7.2	.5	33.0	50.7	3,033	5,460
		B	5.1	36.6	44.3	14.0	1.3	4.3	.8	58.5	21.1	5,372	9,670
		C	....	38.5	46.8	14.7	1.4	3.9	.9	61.6	17.5	5,661	10,190
		D	....	45.2	54.8	....	1.6	4.5	1.0	72.2	20.7	6,639	11,950
AVERAGES		A	37.92	28.43	26.25	10.55	1.25	6.33	.50	35.01	45.20	3,143	5,770
		B	8.62	37.26	37.91	16.17	1.92	3.97	.76	52.20	23.87	4,664	8,391
		C	.....	38.68	42.26	16.98	2.00	3.43	.82	56.20	18.96	5,074	9,197
		D	.....	49.59	50.41	.....	2.58	4.16	.99	68.68	23.25	6,160	11,090

1./ NAME AND LOCATION OF SAMPLE: (1) CAROLSON BROS. (OLD SEXTON MINE), N.W.$\frac{1}{4}$, SEC. 20, T. 12N., R. 13E.; (2) CHET GRAY MINE, STROUL, N.W.$\frac{1}{4}$, SEC. 35, T. 19N., R. 10E.; (3) HODGE MINE, REVA, S.E.$\frac{1}{4}$, SEC. 22, T. 19N., R. 8E.; (4) MENDENHALL PROSPECT, SEC. 1, T. 17N., R. 7E.; (5) NEWCOMB MINE, S.W.$\frac{1}{4}$, SEC. 10, T. 20N., R. 9E.; (6) GIANNONATTI MINE, S.E.$\frac{1}{4}$, SEC. 20, T. 21N., R. 7E.; (7) HILTON MINE, SEC. 6, T. 20N., R. 5E.; (8) KNUDSEN MINE, N.E.$\frac{1}{4}$, SEC. 2, T. 17N., R. 10E.; (9) PELHAM MINE, S.W.$\frac{1}{4}$, SEC. 6, T. 21N., R. 6E.; (10) BAR H MINE, S.W.$\frac{1}{4}$, SEC. 27, T. 19N., R. 8E.; (11) S.W.$\frac{1}{4}$, SEC. 28, T. 19N., R. 8E.; (12) N.W.$\frac{1}{4}$, SEC. 21, T. 19N., R. 8E.; (13) N.W.$\frac{1}{4}$, SEC. 27, T. 19N., R. 8E.; (14) S.E.$\frac{1}{4}$, SEC. 21, T. 19N., R. 8E.; (15) S.E.$\frac{1}{4}$, SEC. 27, T. 19N., R. 8E.; (16) S.E.$\frac{1}{4}$, SEC. 20, T. 21N., R. 7E.

2./ ANALYSTS: B.--H.M.COOPER, U.S. BUREAU OF MINES; G.--E.E.SOMERMEIER AND A.C.FIELDNER, U.S. GEOL. SURVEY AND U.S. BUREAU OF MINES; M.--CHARLES BENTLEY, SOUTH DAKOTA STATE SCHOOL OF MINES.

3./ FORM OF ANALYSIS: (A) AS RECEIVED; (B) AIR DRIED; (C) MOISTURE FREE; (D) MOISTURE AND ASH FREE.

ANALYSES OF FORT UNION COALS[1]

TABLE 3

Name and Location[2]	Analyst[3]	Form of Analyses[4]	Proximate: Moisture	Proximate: Volatile Matter	Proximate: Fixed Carbon	Proximate: Ash	Ultimate: Sulphur	Ultimate: Hydrogen	Ultimate: Nitrogen	Ultimate: Carbon	Ultimate: Oxygen	Heating Values: Calories	Heating Values: B.T.U.
1	M	A	30.65	29.91	34.68	4.76	0.79	.....	.....	.....	....	.....	7,045
		C	.....	43.13	50.51	6.86	1.01	.....	.....	.....	....	.....	10,158
2	G	A	33.3	28.9	27.3	10.5	.76	.....	.....	.....	....	3,865	6,960
		B	15.4	36.7	34.6	13.3	.97	.....	.....	.....	....	4,905	8,830
3	G	A	32.6	30.6	28.5	8.3	1.53	.....	.....	.....	....	4,085	7,360
		C	....	45.4	42.3	12.3	2.27	.....	.....	.....	....	5,070	10,920
4	G	A	40.5	27.1	27.4	5.0	.76	.....	.....	.....	....	3,690	6,640
		C	....	45.5	46.0	8.5	1.28	.....	.....	.....	....	6,205	11,170
Averages		A	34.26	29.13	29.47	7.14	.96	.....	.....	.....	....	3,880	7,001
		C	.....	42.68	43.35	10.24	1.38	.....	.....	.....	....	5,728	10,269

1./ Analyses: 1 and 2 are of samples of South Dakota coal; 3 and 4 of North Dakota coal added for completeness.

2./ Name and location: (1) Warner mine, S.W.$\frac{1}{4}$, Sec. 20, T. 21 N., R. 12 E.
(2) Nelson mine, N.W.$\frac{1}{4}$, Sec. 29, T. 21 N., R. 12 E.
(3) Nipper and Monroe mine, N.W.$\frac{1}{4}$, Sec. 16, T. 129 N., R. 94 W.
(4) Washburn Lignite Coal Co. mine, Sec. 1, T. 142 N., R. 80 W.

3./ Analyst: (M)--Charles Bentley, from Connolly, J. R., and O'Harra, C. C., The Mineral Wealth of the Black Hills, South Dakota School of Mines, Bull. No. 16, p. 396, 1929.
(G)--E. E. Somermeier and A. C. Fieldner, U. S. Geol. Survey and U. S. Bureau of Mines.

4./ Form of Analysis: (A) As received; (B) Air dried; (C) Moisture; (D) Moisture and ash free.

REPRESENTATIVE ANALYSES OF OTHER THAN SOUTH DAKOTA COAL

TABLE 4

Name and Location[1]	Analyst[2]	Form of Analyses[3]	Proximate: Moisture	Proximate: Volatile Matter	Proximate: Fixed Carbon	Ultimate: Ash	Ultimate: Sulphur	Ultimate: Hydrogen	Ultimate: Nitrogen	Ultimate: Carbon	Ultimate: Oxygen	Heating Values: Calories	Heating Values: B.T.U.
1.	G	A	42.1	24.5	25.7	7.7	1.13	....	....	.....	.....	3420	6,160
		B	10.0	38.1	40.0	11.9	1.75	....	....	.....	.....	5310	9,560
		C	....	42.4	44.4	13.2	1.95	....	....	.....	.....	5905	10,630
		D	....	48.8	51.2	....	2.25	....	....	.....	.....	6805	12,250
2.	B	A	11.7	34.0	45.7	8.56	.50	5.28	.95	61.15	23.56	6065	10,910
		B	6.2	36.2	48.5	9.06	.53	4.92	1.02	64.84	19.63	6450	11,610
		C	....	38.6	51.8	9.56	.57	4.52	1.08	69.12	15.15	6870	12,370
		D	....	42.7	57.3	....	.63	5.02	1.20	76.44	16.71	7605	13,690
3.	B	A	3.9	40.1	49.0	6.97	.60	5.49	1.22	72.19	13.53	7160	12,890
		B	2.2	40.8	49.9	7.10	.61	5.39	1.24	73.51	12.15	7290	13,120
		C	....	41.7	51.0	7.26	.62	5.26	1.27	75.15	10.44	7455	13,420
		D	....	45.0	55.0	....	.67	5.67	1.37	81.03	11.26	8035	14,470
4.	C	A	9.13	34.02	48.27	8.58	1.45	....	....	.....	.....	....	11,832
		C	....	37.44	53.12	9.44	1.60	....	....	.....	.....	....	13,021
		D	....	41.34	58.66	....	1.77	....	....	.....	.....	....	14,378

1./ Name and location: (1) Consolidated Coal Co., Lehigh, North Dakota
(2) Canyon City, Colorado (average of 3 analyses)
(3) Kemmerer, Lincoln County, Wyoming (composite from 4 mine samples; best coal of Kemmer field.
(4) Franklin County, Illinois, averages from 21 mines.

2./ Analyst: G.--E. E. Somermeier and A. C. Fieldner, U. S. Geol. Survey and U. S. Bureau of Mines
B.--Pittsburg laboratory of the Bureau of Mines
C.--University of Illinois, U. S. Geol. Survey, and U. S. Bureau of Mines

3./ Form of Analysis: (A) As received; (B) Air dried; (C) Moisture free; (D) Moisture and ash free

HELL CREEK COALS

Coal of the Hell Creek member of the Lance occurs in lenses which are for the most part thin. As previously stated each lense appears to extend under relatively small areas. One or more valuable beds of considerable extent, however, are known to occur. Thickness and limited extent of the Hell Creek coal beds, as a general rule, makes them unfit for profitable mining. Here and there, however, coal beds of this member occur in thicknesses ranging between 2 ft. 10 inches and 7 feet. In some cases these beds underlie several acres, some nearly a square mile, and in some cases possibly underlie areas of considerably greater extent.

Physical and chemical character. Coal of the Hell Creek member is bright, black, has well developed cleavage, and is vertically jointed. It lacks woody texture and structure. In color and other physical properties it thus closely resembles subbituminous coal or other western fields. Moisture content, however, is relatively high in comparison with subbituminous coals but low compared with brown lignites. Three analyses (Table 1) of coals from the lower part of the Hell Creek average slightly below 35 per cent moisture as received. One analysis of coal from the upper part of the member contains 42.5 per cent of moisture as received. This figure is approximately that of average lignite coal. The amount of volatile matter averages a few per cent more than in typical subbituminous coal, but the fixed carbon is proportionately less.

Floor, roof, and overburden. The beds underlying the Hell Creek coals consist in many places of "black jack" or clay. "Black jack" is the term commonly applied by miners of the field to designate carbonaceous shale of appearance very similar to coal. It is worthless, however, as fuel. In other places the floor is clay which in most cases is hard, medium to dark gray, and without bedding laminations or structure. The floor clay in some places, consists of dark brown to drab, structureless, silicious clay, which has the fracture of starch.

Roof materials are sandstone and shale. White, drab, or brown, sandstone of fine texture, in most cases containing much clay, is the most common roof. Where the roof is shale, it is commonly black and carbonaceous, although gray shale occurs in some places. Overburden of these coal beds is fine sandstone, gray to black shale, and clay. Sandstones commonly contain much clay which serves as a binder rendering them less easy to move in stripping than most friable sandstones. The black shales in some cases are tough and fairly hard. Beds of limonite to 10 inches in thickness occur in some sections, but these are commonly broken into blocks less than 1 foot in diameter. No limestones or firmly cemented sandstones have been

observed. Thus, although some of the beds described are removed with difficulty with the horse scraper they are readily removed by machinery such as the drag line or steam shovel.

Localities. Hell Creek coal beds occur in some localities in thickness sufficient for mining. These are grouped together in the eastern part of the outcrop area in Corson, Dewey, and Ziebach Counties and west of the Slim Buttes in Harding County. In the eastern localities valuable beds occur in the vicinity of Isabel and Firesteel in Ziebach and Dewey Counties and near Gopher and Lightcap in Corson County. Several beds of coal in the Hell Creek west of Slim Buttes in Harding County were mapped by the Winchester survey.[1] Only one of these is known to have been mined recently.

Isabel-Firesteel locality. A coal bed northeast of Isabel has been mined in Sec. 22, T. 17 N., R. 22 E. This bed is black and where seen is without interbedded clay. It contains but little sulphur in the form of iron pyrite. Thickness is variable, that measured by the writer being 4 feet 10 inches, and borings made by Ganley Bros. in 1929 at intervals of 300 feet show a maximum thickness of 6 feet 5 inches. A quarter of a mile north of the Midwest Fuel Company strip pit borings show the thickness to be only 3 feet, whereas three quarters of a mile south of the pit the bed apparently is absent.

The following table of succession shows this coal bed and associated beds in strip pit of Midwest Fuel Co. SW¼, Sec. 22, T. 17 N., R. 22 E.

		Feet
4.	Sandstone, fine brownish, friable, soft, lignitic at base	9-30
3.	Shale, bituminous, "Black jack"	0-1/2
2.	Coal, black, little pyrite in thin sheets, no clay seams	4-5/6
1.	Clay, hard gray	exposed
	Total	13 5/6-35 1/3

A coal bed lies northwest of Firesteel in Secs. 7, 8, and 18, T. 17 N., R. 22 E. It occurs in approximately the same position in the Hell Creek as the bed north of Isabel. The table of succession which follows shows the coal as it was exposed in the Hammerly mine.

Section of coal and associated beds in Hammerly mine in the N.E.¼, Sec. 18, T. 17 N., R. 23 E.

		Feet
6.	Clay, shale, brown, bedding obscure	3-4
5.	Siltstone and fine sandstone, light gray, weathers buff and yellow	7-8

1./ Winchester, D. E., and others, Maps of Harding County accompany U. S. Geol. Survey Bull. 627, 1916.

4.	Clay shale, hard, medium gray, bedding obscure or absent	7-8
3.	Shale, carbonaceous, "black jack"	3/4-5/6
2.	Coal, clean, black, bright	5
1.	Clay, hard, gray	exposed
	Total	22 3/4-25 5/6

A coal bed, possibly the same as that of the Hammerly mine, is present north, northeast, and southwest of Firesteel in Secs. 15, 16, and 21, T. 17 N., R. 23 E. where the thickness has been reported as ranging between 5 and 7 feet.

Coal beds of the Hell Creek member occur also southwest of Isabel and south of Firesteel. The tables of succession which follow indicate the thickness of the coal beds and the character and thickness of the associated strata southwest of Isabel.

Section of Hell Creek coal exposed in Hammond strip mine in N.E.¼, Sec. 8, T. 16 N., R. 22 E.

		Feet
5.	Sandstone, friable, and slope mantle	4-12
4.	Shale, brown to drab, brittle	9-12
3.	Shale, black, carbonaceous	2
2.	Coal, black	3½
1.	Shale, black, bony coal or "black jack"	5/6-1
	Total	19 1/3

Section exposed in Reichert Mine in the N.W.¼, Sec. 7, T. 16 N., R. 22 E.

5.	Sandstone, friable, gray to buff, cross-bedded, fine, claylike at top	10-12
4.	Coal, black	1/6-1/4
3.	Shale, carbonaceous, "black jack" or bone	3/4-1
2.	Shale, black and carbonaceous at top, dark gray at base, tough	2
1.	Coal, black	4
	Total	16 11/12-19 1/4

Coal of similar character and relations occurs along Irish Creek where the average thickness is reported as five feet. The succession in which the coal occurs is shown in the table which follows:

Section of coal and associated beds exposed in the Tidball (Rosander) mine in the N.E.¼, Sec. 23, T. 16 N., R. 20 E.

		Feet
7.	Covered, probably shale and friable sandstone	30
6.	Shale and friable sandstone	6

5.	Shale, brown, carbonaceous, and fine; hard white sandstone in lenses, sandstone cuts through shale and rests on coal along 200-300 feet of the outcrop -	2-6
4.	Shale, black, carbonaceous, "black jack", cut out by overlying white sandstone in places - - - - - - - -	0-1
3.	Coal, black, bright- - - - - - - - - - - - - - - - - -	5
2.	Shale, black carbonaceous, bone or "black jack"- - -	5/6
1.	Clay, hard gray, structureless - - - - - - - - - - -	1
	Total- - - - - - - -	44 5/6-49 5/6

Gopher locality. In the Gopher locality clean, black vertically jointed coal occurs in a bed of sufficient thickness for mining. The succession in this locality is well exposed in mines in the southern part of Sec. 7, T. 18 N., R. 20 E., as shown in the table which follows:

Section of Hell Creek coal and associated strata exposed in the Kennedy and Anderson mines in the S.E.¼, S.W.¼, and S.W.¼, S.E.¼, Sec. 7, T. 18 N., R. 20 E.

		Feet
4.	Sandstone, light gray, fine, much clay, bedding obscurely crossbedded and thin bedded, logs of glance coal in lower 1 foot. Erodes to badlands- - - - - -	34
3.	Coal, black, bright, brittle, vertically jointed - -	5½
2.	Shale, black, carbonaceous - - - - - - - - - - - - -	3/4
1.	Clay, drab at top, dark brown below, sandy, starchy fracture -	7
	Total- - - - - - - - - - - -	47¼

Lightcap Locality. A very similar succession including a coal bed has been observed southwest of Lightcap in Secs. 25-36, T. 19 N., R. 21 E., where there are several small local stripping mines. The similarity of this succession with that of the Gopher locality suggests that the coal of the two localities may be continuous. The succession near Lightcap is given in the table which follows:

		Feet
4.	Clays, and sandy clays, light, medium and dark gray, in beds from few inches to 15 feet of one shade, beds continuous for ¼ mile or more. Limonite concretions (bog iron in masses up to 10 inches thick and 6 feet in diameter) especially abundant in the upper part -	200+
3.	Sandstone, fine, light gray- - - - - - - - - - - - - -	15
2.	Coal, black, laminated, bright, considerable glance coal, jointed vertically - - - - - - - - - - - - - - -	4-4½
1.	Clay, underclay, brown, starchy fracture - - - - - -	5+
	Total- - - - - - - - - - - -	224+

Slim Butte Locality. In Harding County west of Slim Buttes there are several beds of coal in the upper part of the Hell Creek member. Most of these beds, however, are thin,

lenticular, and many are impure. The most valuable bed known to the writer occurs in Sec. 29, T. 19 N., R. 7 W. It is without clay partings and pyrite was not observed. The coal has been mined from a slope driven in on the outcrop. Although roof conditions are poor this bed deserves further investigation as a stripping prospect. The succession in which the coal occurs consists of clays, shales, and sandstones. The following section was made in the Goode mine in the S.W.¼, Sec. 29, T. 19 N., R. 7 W.

Section of upper Hell Creek coal exposed in the Goode Mine in the S.W.¼, Sec. 29, T. 19 N., R. 7 W.

		Feet
3.	Shale, gray	3
2.	Coal, black, hard, badly air slacked 75 feet along slope	7
1.	Clay, hard, gray	1
	Total	11

LUDLOW COALS

The coal beds of the Ludlow member of the Lance are the most persistent and the thickest of the South Dakota field. In many places a coal bed occurs at the base of the member. Several fairly persistent beds occur in eastern Harding County. The thickest bed observed by the writer is somewhat more than 14 feet thick.

Coal beds of the Ludlow member are distributed throughout the formation. In many places, notably in Perkins County and eastern Harding County, a bed lies at the base of the member. Around the North and South Cave Hills mesas beds of coal lie near the top of the Ludlow. Several beds of coal which lie between these highest and lowest ones are particularly well developed in the region about and between Ludlow and Ralph.

Physical and chemical character. Ludlow coals are typical lignite for the most part. When fresh the coal is mostly brown in color although lenses and beds of brownish black and black are common. Indeed, in some localities, the greater part of the coal is black with only minor amounts of interbedded brown coal. Both brown and black varieties produce a brown streak. The brown part of the coal is tough, woody and fibrous, whereas the black variety is more or less brittle and contains much glance coal. In beds mostly made up of black coal cleavage is parallel to the bedding and vertical jointing is common. Fusain, or mineral charcoal, is very common in these beds in some localities.

The chemical composition of the coal beds of this member is typical of lignite. The moisture content is high, the average of available analyses (Table 2) being 37.92 per cent. Drying of the fuel in air reduces this percentage to an average of 8.62. Fixed carbon in the coal as received averages 26.25 per cent, and volatile matter averages 28.43. In the moisture free coal fixed carbon is 37.91 per cent and volatile matter is 37.26 per cent. The average percentage of ash in Ludlow coals is 10.55 per cent as received or 16.17 per cent in moisture free samples. This figure is somewhat higher than the average for the lower Hell Creek beds, and is a little higher than that of the average Hell Creek coal. The analyses indicate, however, that the ash content of certain Ludlow beds in certain localities closely approximates that of the average Hell Creek coal. Some Ludlow beds contain a very high percentage of ash. Sulphur is somewhat more abundant in most Ludlow coals than in the Hell Creek beds although sulphur content of South Dakota coals is low as compared with that of eastern coal. Heating value of Ludlow coals, as indicated by analyses, is somewhat lower than those of the Hell Creek, the average moisture free heating value of the former being 9197 B.T.U. as compared with 10696 B.T.U. in the latter.

Floor, roof, and overburden. The Ludlow coal beds are underlain by beds of hard gray structureless clay. In some cases the material is also tough. In the Stoneville locality the floor is tough, black, carbonaceous shale. The roof in many places is shale, shale and sandstone, or sandstone. Over the coal beds of the lower part of the Ludlow these beds are relatively soft and probably would form only fair roof for underground projects. West of the Slim Buttes, shale and sandstone beds have proven satisfactory roof materials. The coal bed in the Stoneville locality, northern Meade County, is overlain by tough carbonaceous shale or "black jack" which forms a very satisfactory roof.

Overburden varies from a few feet to a few hundred feet in thickness. The beds which must be removed in stripping operations consist of shales and sandstone which ordinarily are removed without difficulty. In many places, however, large sandstone concretions must be removed with the overburden. These are particularly troublesome in small scale operations. No beds occur over the available Ludlow coals which cannot be readily removed by heavy power machinery.

Localities. In the pages which follow representative localities are described in which Ludlow coal beds occur. For descriptions of other beds and localities and for the extent of these and other beds, the reader is referred to the report and maps of the Winchester survey.[1] Typical exposures occur in the vicinity of Coal Springs, southwest of Bison,

1./ Winchester, D. E., The Lignite field of Northwestern South Dakota, U. S. Geol. Survey Bull. 627, 1916.

and near Strool in Perkins County and near Reva, west of the Slim Buttes, south of Ralph, southeast of Ludlow, and near the Cave Hills in Harding County. The coal bed mined in northern Meade County in the vicinity of Stoneville is described here as Ludlow, although the position of these beds has not been determined.

Coal Springs locality. Coal beds lying at and near the base of the Ludlow member have been mined for many years in the vicinity of Coal Springs, where coal has been mined both north and south of Coal Springs, P.O. Wherever exposed in this vicinity, however, coal at this position is split by shale partings into benches too thin to be of more than local value. The table of succession in the Sundermeyer mine given on a preceding page, (p. 14) is typical of the occurrence of the coal in this locality. A somewhat less detailed table of this succession is repeated here for the convenience of the reader.

Section exposed in the Sundermeyer strip mine in the N.E.¼, Sec. 20, T. 17 N., R. 17 E.

		Feet
8.	Sandstone, log concretions in upper 20 feet - - - -	36
7.	Shale and sandstone in alternating thin beds- - - -	9
6.	Coal, black, much glance- - - - - - - - - - - - - - -	2½
5.	Clay, shale, medium gray- - - - - - - - - - - - - - -	1
4.	Coal black, top 6 inches bony, pyrite masses to six inches in diameter- - - - - - - - - - - - - - - - - - -	2 1/3
3.	Clay shale, medium to dark gray - - - - - - - - - - -	¼-2/3
2.	Coal, black, vertically jointed, fairly hard, much glance- -	1
1.	Clay, drab brown- - - - - - - - - - - - - - - - - - -	1
	Total - - - - - - - - - - - - -	53

Bison locality. Coal which occurs at the base of the Ludlow has been mined for many years southwest of Bison. In this locality a bed, possibly the lower bench of the Coal Springs locality, thickens to 5 feet. This coal is black throughout, hard, bright, and vertically jointed. The lower bed contains no clay or shale, but pyrite occurs in masses of a size up to one inch thick by 4 inches in diameter which appear, however, to average a size sufficiently large to be readily discarded in mining. The tables which follow show the coal and associated beds, the first at the Carlson mine in the N. W. ¼, Sec. 20, T. 17 N., R. 13 E., and the second in the Hafner Mine in the S. E. ¼, Sec. 17, T. 17 N., R. 13 E.

Section of basal Ludlow exposed in the Carlson mine in the N. W. ¼, Sec. 20, T. 17 N., R. 13 E.

		Feet
8.	Grass covered slope	10
7.	Shale, medium gray, contains plant remains, leaves and stems	11
6.	Coal, impure, clay streaked	1
5.	Shale, medium gray, fairly hard, contains plant remains	3
4.	Coal, impure, thinly laminated, with thin clay streaks	1½
3.	Shale, lignitic, brown	¼
2.	Coal, black, joints into cubical blocks	5
1.	Clay, hard, gray, somewhat siliceous, contains fossil rootlets	5
	Total	36 3/4

Section of the Ludlow exposed in the Hafner mine in the S.E.¼, Sec. 17, T. 17 N., R. 13 E.

		Feet
8.	Soil, sandy	1
7.	Sandstone and sandy shale, contains large log concretions	5
6.	Coal, impure, thinly laminated, thin clay streaks	1/3-1
5.	Shale, light medium to medium dark gray, abundant plant leaves where thinnest	2½-18
4.	Coal, impure, thin clay streaks	3/4-1¼
3.	Shale, medium gray, prominently jointed from top to base, considerably fractured into angular pieces	9-15
2.	Coal, black, bright, horizontally bedded, hard, vertically jointed	4½-5
1.	Clay, tough, medium gray, jointed; contains rootlets	2
	Total	18 1/12-68¼

Strool locality. Coal at the base of the Ludlow member of the Lance has been mined east and somewhat south of Strool. Northwest of Strool a coal higher in the member is mined.

The coal to the east of Strool is only a few miles from that southwest of Bison and apparently lies in the same stratigraphic position. As in the Bison locality the coal is black and bright, but where observed is thinner. In some places it contains considerable pyrite in flattish masses arranged along the bedding planes.

The succession in which the coal occurs in the Van Lee Mine is shown in the following table:

Section of basal Ludlow exposed in the Van Lee Mine in the S.W.¼, Sec. 31, T. 18 N., R. 12 E.

		Feet
8.	Soil	1
7.	Sandstone, buff, fine, thin bedded	2½
6.	Coal, impure	1/12-5/6
5.	Sandstone, gray, fine, contains large gray concretions,	

	one being from 8 to 11 inches thick, 80 feet long; reported more than 40 feet wide - - - - - - - - - - -	3-4
4.	Clay ironstone, concretionary - - - - - - - - - - -	2
3.	Shale, and shaly sandstone, for the most part cross-bedded- -	3-7
2.	Coal, black, bright, flattish masses of pyrite along bedding planes- - - - - - - - - - - - - - - - -	3-4
1.	Clay, hard, medium gray - - - - - - - - - - - - - - - -	exposed
	Total - - - - - - - -	11 7/12-21 1/3

Coal mined northwest of Strool is very different from that in the section described above. This bed contains much dark brown and brownish black coal, is tough and woody, and also contains much fusain, or mineral charcoal, where it has been observed. The succession in which it occurs is different from that east of Strool and southwest of Bison. The table of succession which follows shows the coal and the strata with which it is associated.

Section of Ludlow strata exposed in the Gray mine in the S.W.¼, Sec. 26, T. 19 N., R. 10 E.

		Feet
6.	Sandstone, buff, fine, friable, homogeneous, massive	11
5.	Sandstone and shale, interbedded; sandstone, buff, shale light to medium gray; in alternating beds from 1 to 9 inches thick. Oblate concretions of hard, bluish gray, limy sandstone to 4 by 8 feet or more at top. Concretions present in upper half- - - - - - - -	20
4.	Sandstone, buff, friable, massive, but thin-bedded -	10
3.	Sandstone and shale, interbedded in thin layers; sandstone buff, shale medium gray- - - - - - - - - - -	3
2.	Coal, black to brownish black, vertically jointed, ½ inch of clay, 1 foot from top- - - - - - - - - - - -	2
1.	Coal, tough, brownish black, somewhat bony, much fusain -1	5/6-3 5/6
	Total- - - - - - - - - -	36 5/6

Reva locality. Coal is mined for local use between Reva and Slim Buttes. A bed mined at the Hodge mine contains some brown coal, but most of it is black in color. The bed here is without clay partings and appears to be of good quality. The coal ranges between 12 and 14 feet thick in the Hodge mine. The table which follows shows the coal and overlying beds at this place.

Section of Ludlow in the Hodge strip mine in the N.E.¼, Sec. 17, T. 18 N., R. 8 E.

		Feet
3.	Rubble, derived from White River beds - - - - - - - - -	1½
2.	Shale, medium gray, silty texture, well preserved	

	leaves of deciduous trees in lower 3 feet - - - - - - - -	3
1.	Coal, mostly black, some brown- - - - - - - - - - - - - -	12-14
	Total - - - - - - - - - - - - -	$16\frac{1}{2}$-$18\frac{1}{2}$

Locality West of Slim Buttes. Two beds of coal which occur in the Ludlow member along the west flank of the Slim Buttes mesa are particularly well exposed in Sec. 36, T. 18 N., R. 7 E. The lower of these beds is thick and has been mined by drifts for local use. Where observed, this bed consists of two benches separated by clay shale which varies in thickness from 3 inches to 3 feet within a half mile. The lower bench is jointed vertically into blocks of roughly cubical shape. The upper bench is tough and somewhat woody. The thickest exposure of this coal was noted in the Olsrud mine in the N.W.$\frac{1}{4}$, S.E.$\frac{1}{4}$, Sec. 36, T. 18 N., R. 7 E. This exposure and one less than a half mile south are shown with their associated beds in the tables of succession which follow:

Section of the Ludlow coal and associated beds exposed along west flank of Slim Buttes in the Olsrud mine in the N.W.$\frac{1}{4}$, S.E.$\frac{1}{4}$, Sec. 36, T. 18 N., R. 7 E.

		Feet
6.	Shale, sandy, buff, poorly exposed, exposed along road-	50
5.	Shale, gray, and buff, thin bedded- - - - - - - - - - -	8
4.	Coal, black and brown, tough- - - - - - - - - - - -	7-8
3.	Clay shale, gray- - - - - - - - - - - - - - - - - - -	$\frac{1}{4}$
2.	Coal, black, some brown - - - - - - - - - - - - - - -	6-7 $14\frac{1}{2}$
1.	Clay, blue gray; hard - - - - - - - - - - - - - - - -	1
	Total - - - - - - - - - - - - -	$73\frac{1}{2}$

Section of Ludlow coal and overlying beds exposed at the opening of the Geisniss mine in the S.W.$\frac{1}{4}$, S.E.$\frac{1}{4}$, Sec. 36, T. 18 N., R. 7 E.

		Feet
4.	Shale, gray and buff, thin bedded - - - - - - - - - - - -	4
3.	Coal, black, some brown, woody and tough- - - - - - - -	4-5
2.	Clay, shale, light gray, structureless- - - - - - - - -	3
1.	Coal, black, some brown - - - - - - - - - - - - - - - -	$7\frac{1}{2}$
	Total - - - - - - - - - - - - -	$18\frac{1}{2}$-$19\frac{1}{2}$

Ralph locality. A thick bed of coal has been mined for many years southwest of Ralph in northeastern Harding County. This coal like that in the bed last described is split into two benches by a clay parting. Here, however, no differences in character between the upper and lower benches are apparent. Both benches were black in color but somewhat weathered where observed. The bed is well exposed at the opening of the Pintar mine in Sec. 35, T. 21 N., R. 8 E. where the following section was made.

Section of Ludlow coal and overlying beds exposed in and above the opening of the Pintar mine in Sec. 35, T. 21 N., R. 8 E.

		Feet
5.	Shale and sandstone, shale sandy and sandstone argillaceous, interbedded- - - - - - - - - - - - - - - -	8
4.	Shale, pinkish gray, irregularly jointed - - - - - - -	3
3.	Coal, black, vertically jointed- - - - - - - - - - - -	7¼
2.	Clay, light gray - - - - - - - - - - - - - - - - - - -	1/2-5/6
1.	Coal, black, hard- - - - - - - - - - - - - - - - - - -	5
	Total- - - - - - - - -	23 3/4-24 1/12

Ludlow locality. Lignite has been mined in this locality for many years. Two thick beds were mapped in this locality by Winchester survey.[1] The Gionnanati bed occurs in the upper part of the Ludlow and the Widow Clark 50 to 70 feet below it. The coal of the Gionnanati bed as observed is black for the most part. It contains much brown and woody material, however. The coal is tough and breaks away from the bed when mined in flat, irregularly shaped pieces. This bed and the overlying strata are described in the table of succession which follows:

Section of the Gionnanati coal bed and overlying strata in the mine in the N.E.¼, Sec. 29, T. 21 N., R. 7 E.

		Feet
3.	Sandstone, hard, ripplemarked- - - - - - - - - - - -	4
2.	Sandstone, friable, buff and yellow, micaceous; crossbedded and massive in lower 13 feet; elongate sandstone concretions to 8 inches thick by 3 feet wide by 12 feet long in basal part- - - - - - - - - - - - -	71
1.	Coal, black, with considerable brown, tough- - - - -	9
	Total- - - - - - - - - - -	84

The total thickness of the coal bed is not exposed here. Two or more feet of coal are reported below that exposed, separated from a thick lower bench of hard black coal by a clay bed one foot thick.

A coal bed possibly stratigraphically higher than the Gionnanati bed has been mined in recent years near the North Cave Hills in the S.W.¼, Sec. 26, T. 22 N., R. 5 E. The character and thickness of this bed together with associated strata are shown in the following table:

Section of upper Ludlow coal and associated beds exposed in the Doane strip mine in the S.W.¼, Sec. 26, T. 22 N., R. 5 E.

1./ Winchester, D. E. and others, op. cit., U. S. Geol. Survey Bull. 627, Geologic map of Harding County, and pp. 94-95, 1918.

		Feet
4.	Sandstone and shale, interbedded; sandstone shaly, drab; shale brown; 3 inches of highly lignitic shale one foot from base	8
3.	Coal, impure, weathered	2½
2.	Coal, brown and black, woody parts brown, somewhat tough	5½ 8
1.	Clay, light gray	5
	Total	21

Locality south of Cave Hills. Lignite has been mined in the southern part of the South Cave Hills for 15 years or more. The beds from which coal is obtained occur in the upper 90 feet of the Ludlow member. The most important bed is the Hilton bed, formerly mined in the old Hilton mine, in Sec. 6, T. 20 N. R. 5 E., and this bed as shown in the table of succession on a preceding page (P. 15) is split into five benches by thin clay partings. The lower three benches approximate one foot each in thickness, the uppermost is 16 to 17 inches in thickness, and the fourth bench is 7½ feet thick. This thick bench is composed of coal which is mostly black, but it contains some brown woody material. In mining the coal is taken out in tough sheets.

Stoneville locality. The southernmost minable coal beds of South Dakota occur northeast of Stoneville, northern Meade County. Mines have been operated in this locality for at least 8 years. Coal is recovered through shafts which are sunk to the bed which lies between 30 and 55 feet below the surface at the mines. The bed is reported to range between 30 and 53 inches in thickness.

The lower part of the Stoneville coal bed is reported by operators to be composed largely of dull black coal whereas the upper foot is bright. Some pyrite is also reported.

On the table which follows, the succession in which the coal occurs is shown by the shaft log of the Stainbrook mine in the N.W.¼, N.W.¼, Sec. 10, T. 9 N., R. 12 E., modified from a report by Mr. E. E. Stainbrook:

		Feet
6.	Surface	
5.	Clay and shale; clay gray, shale brown	16
4.	Sandstone, hard, white	18
3.	Shale, black, carbonaceous, "black jack"	1-3
2.	Coal	3-4 5/12
1.	Shale, black, hard, carbonaceous, "black jack"	4
	Depth Total	39

FORT UNION COALS

The Fort Union formation is the youngest coal bearing formation in South Dakota. At one time coal beds of this formation covered a fairly wide area of the coal field but erosion has reduced the former extent to small outliers underlying only the higher divides. Most of the Fort Union coal occurs in northern Perkins county in the vicinity of Lodgepole P.O., although small patches occur southeast of Ellingson and near the middle of the northern boundary of Perkins County.

Two or more coal beds occur in the Fort Union. The lower bed which lies above the basal sandstone, however, appears to be the only bed of sufficient thickness for profitable mining.

Physical and chemical character. The coal of the Fort Union like that of the Hell Creek member of the Lance is black when fresh. Bright and dull coal commonly occur in approximately equal amounts as thin laminae. The coal is commonly fairly brittle, the tough character of Ludlow coals being absent.

Analyses (Table 3) suggest that in chemical as well as physical character the Fort Union coal is similar to coals of the lower Hell Creek. Moisture content as received averages[1] 34.26 per cent, volatile matter 29.13 per cent, and fixed carbon 29.39. Dry samples average 42.68 per cent, volatile matter, and 43.35 fixed carbon. Heating values average 7001 B.T.U. as received and 10,269 for moisture free samples.

Floor, roof and overburden. Since Fort Union coal is commonly mined in the South Dakota field by drifting in on the outcrop, roof and floor conditions are of importance. Hard gray clay underlies the coal in all of the mines studied. This material is an excellent floor which should not buckle or squeeze. Thickness of the coal, however, permits leaving the lower part of the bed as a floor. Shale of light gray color overlies the coal in most places. When fresh this shale should form a good roof material. When weathered, however, it fractures into small angular fragments which permit roof falls and rapid subsidence. It is the common practice in the Fort Union area to leave from 2 to 4 feet of coal as a roof which is satisfactory in most cases. The overburden consists of shale and sandstone. The coal is overlain in many places by shale 18 to 21 feet thick which is in turn overlain by silts which grade upward into sandstone. Elsewhere only 2 feet of shale lie between coal and sandstone.

1./ Averages of Fort Union coals include two analyses of North Dakota coal.

Localities

Lodgepole locality. As previously stated, the region around Lodgepole comprises the greater portion of the Fort Union coal of the State. The coal underlies two important areas one south and one north of Lodgepole. The tables of succession which follow indicate the position and thickness of the coal and associated beds, the first south of Lodgepole P.O. and the second north.

Section of Fort Union coal and associated strata exposed below, in and above the Warner mine in the S.W.¼, Sec. 20, T. 21 N., R. 12 E.

		Feet
10.	Float, quartzite boulders- - - - - - - - - - - - - - -	
9.	Covered- -	10
8.	Sandstone, white and yellow, friable, with ovoid concretions of cross bedded sandstone to 10 feet in diameter- -	18
7.	Silt, sandy, brownish yellow - - - - - - - - - - - - -	10
6.	Bone, brownish black - - - - - - - - - - - - - - - - -	2
5.	Coal, black- -	1
4.	Clay, brown, hard- - - - - - - - - - - - - - - - - - -	1
3.	Shale, gray, tough - - - - - - - - - - - - - - - - - -	18
2.	Coal, black, some pyrite - - - - - - - - - - - - - - -	8
1.	Clay, gray, hard - - - - - - - - - - - - - - - - - - -	1
	Total- - - - - - - - - - - -	69

Section exposed at opening of Clark mine in the N.E.¼, Sec. 32, T. 22 N., R. 12 E.

4.	Sandstone- -	20
3.	Clay shale gray- - - - - - - - - - - - - - - - - - - -	4
2.	Coal, black, few spherical masses of pyrite to 1½ inches -	8
1.	Clay, hard, gray - - - - - - - - - - - - - - - - - - -	1
	Total - - - - - - - - - - -	33

Ellingson locality. Fort Union coal which is apparently the Lodgepole bed occurs in a narrow flat topped ridge which forms the divide between North Fork and South Fork of Grand River. This small area lies six miles south and three miles east of Ellingson. Here the coal lies close to the surface and resulting roof conditions are poor. The table which follows shows the succession at this locality.

Section of Fort Union at opening of the Johnson mine in the N.E.¼, Sec. 9, T. 21 N., R. 11 E.

		Feet
6.	Shale, light gray- - - - - - - - - - - - - - - - - - -	7
5.	Sandstone, hard- - - - - - - - - - - - - - - - - - - -	½

4.	Shale, light gray, weathered yellow and white- - - - -	21
3.	Shale, brown -	1/3
2.	Coal, black- -	7
1.	Clay, underclay, gray, hard- - - - - - - - - - - - - -	1
	Total- - - - - - - - - - - - -	36 5/6

Wolf Butte locality. Several small areas underlain by coal occur in the vicinity of Wolf Butte. Locally at least the coal thickens to an average of 9 feet. Coal of this thickness with the usual character of the Lodgepole bed is well exposed at the Butts mine. The succession at this mine is given in the table which follows:

Section of Fort Union coal and associated beds exposed at the Butts mine in the S.E.¼, Sec. 34, T. 22 N., R. 12 E.

		Feet
4.	Covered slope- - - - - - - - - - - - - - - - - - - -	
3.	Shale, gray, weathers white- - - - - - - - - - - - -	20
2.	Coal, black, average 9 feet thick- - - - - - - - - -	8-10
1.	Clay -	1
	Total- - - - - - - - - - - -	29-31