DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 627

THE LIGNITE FIELD OF NORTHWESTERN SOUTH DAKOTA

BY

DEAN E. WINCHESTER, C. J. HARES, E. RUSSELL LLOYD, AND E. M. PARKS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
25 CENTS PER COPY

CONTENTS.

	Page.
Introduction	7
Location and extent	7
Object of the survey	7
Personnel and acknowledgments	7
Previous work	8
Land survey	9
Field work	9
Geography	10
Surface features	10
Drainage and water supply	11
Climate and vegetation	13
Settlement	14
Geology	14
General outline	14
Cretaceous system	17
Pierre shale	17
Fox Hills sandstone	17
Tertiary (?) system	18
Lance formation	18
General character	18
Lower part of the Lance formation	19
Ludlow lignitic member	19
Cannonball marine member	22
Fossils	23
Tertiary system	26
Fort Union formation (Eocene)	26
Later Tertiary formations	31
White River formation (Oligocene)	32
Arikaree (?) sandstone (Miocene?)	34
Quaternary system	35
Structure	36
Lignite	38
Location and extent	38
Physical character	39
Chemical composition	40
Available lignite	46
Detailed descriptions by townships	46
T. 16 N., R. 1 E.	46
T. 17 N., R. 1 E.	47
T. 18 N., R. 1 E	47
T. 19 N., R. 1 E.	47
T. 20 N., R. 1 E.	48
T. 21 N., R. 1 E.	49
T. 22 N., R. 1 E.	49
T. 23 N., R. 1 E.	50
T. 16 N., R. 2 E.	50

Lignite—Continued.
Detailed description by townships—Continued Page.
T. 17 N., R. 2 E. 50
T. 18 N., R. 2 E. 51
T. 19 N., R. 2 E. 51
T. 20 N., R. 2 E. 51
T. 21 N., R. 2 E. 52
T. 22 N., R. 2 E. 53
T. 23 N., R. 2 E. 54
T. 16 N., R. 3 E. 54
T. 17 N., R. 3 E. 54
T. 18 N., R. 3 E. 55
T. 19 N., R. 3 E. 55
T. 20 N., R. 3 E. 56
T. 21 N., R. 3 E. 56
T. 22 N., R. 3 E. 57
T. 23 N., R. 3 E. 58
T. 16 N., R. 4 E. 59
T. 17 N., R. 4 E. 59
Tps. 18 and 19 N., R. 4 E. 59
T. 20 N., R. 4 E. 60
T. 21 N., R. 4 E. 61
T. 22 N., R. 4 E. 63
T. 23 N., R. 4 E. 65
Tps. 16, 17, 18, and 19 N., R. 5 E. 66
T. 20 N., R. 5 E. 66
T. 21 N., R. 5 E. 68
T. 22 N., R. 5 E. 71
T. 23 N., R. 5 E. 74
Tps. 16, 17, 18, 19, and 20 N., R. 6 E. 75
T. 21 N., R. 6 E. 76
T. 22 N., R. 6 E. 79
T. 23 N., R. 6 E. 81
T. 16 N., R. 7 E. 82
T. 17 N., R. 7 E. 83
T. 18 N., R. 7 E. 85
T. 19 N., R. 7 E. 87
T. 20 N., R. 7 E. 90
T. 21 N., R. 7 E. 93
T. 22 N., R. 7 E. 95
T. 23 N., R. 7 E. 96
T. 15 N., R. 8 E. 97
T. 16 N., R. 8 E. 98
T. 17 N., R. 8 E. 98
T. 18 N., R. 8 E. 101
T. 19 N., R. 8 E. 103
T. 20 N., R. 8 E. 105
T. 21 N., R. 8 E. 107
T. 22 N., R. 8 E. 109
T. 23 N., R. 8 E. 110
T. 15 N., R. 9 E. 112
T. 16 N., R. 9 E. 112
T. 17 N., R. 9 E. 113
T. 18 N., R. 9 E. 114

Lignite—Continued.
Detailed description by townships—Continued. Page.
T. 19 N., R. 9 E. 115
T. 20 N., R. 9 E. 117
T. 21 N., R. 9 E. 119
T. 22 N., R. 9 E. 121
T. 23 N., R. 9 E. 123
T. 16 N., R. 10 E. 124
T. 17 N., R. 10 E. 125
T. 18 N., R. 10 E. 126
T. 19 N., R. 10 E. 127
T. 20 N., R. 10 E. 129
T. 21 N., R. 10 E. 130
T. 22 N., R. 10 E. 132
T. 23 N., R. 10 E. 132
T. 16 N., R. 11 E. 133
T. 17 N., R. 11 E. 133
T. 18 N., R. 11 E. 135
T. 19 N., R. 11 E. 135
T. 20 N., R. 11 E. 136
T. 21 N., R. 11 E. 137
T. 22 N., R. 11 E. 138
T. 23 N., R. 11 E. 139
T. 16 N., R. 12 E. 140
T. 17 N., R. 12 E. 140
T. 18 N., R. 12 E. 141
T. 19 N., R. 12 E. 141
T. 20 N., R. 12 E. 142
T. 21 N., R. 12 E. 142
T. 22 N., R. 12 E. 143
T. 23 N., R. 12 E. 144
T. 16 N., R. 13 E. 145
T. 17 N., R. 13 E. 145
T. 18 N., R. 13 E. 146
T. 19 N., R. 13 E. 147
T. 20 N., R. 13 E. 147
T. 21 N., R. 13 E. 148
T. 22 N., R. 13 E. 148
T. 23 N., R. 13 E. 149
T. 16 N., R. 14 E. 149
T. 17 N., R. 14 E. 149
T. 18 N., R. 14 E. 150
T. 19 N., R. 14 E. 150
T. 20 N., R. 14 E. 151
T. 21 N., R. 14 E. 152
T. 22 N., R. 14 E. 153
T. 23 N., R. 14 E. 153
T. 16 N., R. 15 E. 153
T. 17 N., R. 15 E. 156
T. 18 N., R. 15 E. 156
T. 19 N., R. 15 E. 157
T. 20 N., R. 15 E. 158
T. 21 N., R. 15 E. 159
Tps. 22 and 23 N., R. 15 E. 159

Lignite—Continued.
Detailed description by townships—Continued. Page.
Tps. 16 and 17 N., R. 16 E. 160
Tps. 18 and 19 N., R. 16 E. 160
Tps. 20, 21, 22, and 23 N., R. 16 E. 162
T. 17 N., R. 17 E. 163
Tps. 18 19, 20, 21, 22, and 23 N., R. 17 E. 163
Bibliography 164
Index 167

ILLUSTRATIONS.

Page.
PLATE I. Geologic map of Harding County, S. Dak. In pocket.
II. Geologic map of Perkins County, S. Dak. In pocket.
III. *A*, West face of South Cave Hills, Harding County, S. Dak.; *B*, Landslide beds of White River formation north of Slim Buttes, Harding County, S. Dak. 10
IV. *A*, One of the small buttes northeast of Bison, S. Dak., showing White River formation resting on Lance formation; *B*, South face of Slim Buttes, showing cliff formed by Arikaree (?) sandstone... 32
V. *A*, Knudsen mine, showing the general character of the strip pit mines of the region; *B*, Jones lignite mine north of Strool, S. Dak.. 44
VI. Lignite sections in Harding County, S. Dak. 82
VII. Lignite sections in Harding County, S. Dak. 92
VIII. Lignite sections in Harding County, S. Dak. 106
IX. Lignite sections in Harding County, S. Dak. 124
X. Lignite sections in Perkins County, S. Dak. 154
XI. Lignite sections in Perkins and Harding counties, S. Dak. 162
FIGURE 1. Key map showing the area examined by each field party 8
2. Diagram showing the interrelation of the members of the Lance formation 15
3. Map showing geologic structure of the lignite field of northwestern South Dakota 37

THE LIGNITE FIELD OF NORTHWESTERN SOUTH DAKOTA.

By Dean E. Winchester, C. J. Hares, E. Russell Lloyd, and E. M. Parks.

INTRODUCTION.

LOCATION AND EXTENT.

The field described in this report (see fig. 1) is a rectangular area of about 4,900 square miles in Perkins and Harding counties, S. Dak., and includes nearly all the valuable lignite of the State. It extends from the Montana line to the east line of Perkins County, in R. 17 E. of the Black Hills meridian, and from T. 15 N. to the North Dakota State line.

Lignite is present in nearly every part of the field, but in most places the beds are thin and lenticular. Probably the greater part of the South Dakota lignite will never become of more than local economic importance. A few districts, however, contain beds sufficiently thick and persistent to warrant commercial development. Only about 8 per cent of the total area, or approximately 390 square miles, is underlain by lignite having a thickness of 2 feet 10 inches or more.

OBJECT OF THE SURVEY.

In July, 1910, a large part of the public land in Perkins and Harding counties, S. Dak., was withdrawn from entry on the supposition that it probably contained valuable beds of lignite. This action made it impossible for settlers to obtain patents, which would cover underground as well as surface rights, until the land should be examined and classified by the Geological Survey. This report embraces the results of geologic examinations made during the summers of 1911 and 1912, for the purpose of classifying the area as coal land or non-coal land.

PERSONNEL AND ACKNOWLEDGMENTS.

During the summer of 1911 two field parties were engaged in geologic work in northwestern South Dakota. One, under the direction of E. M. Parks, assisted by H. M. Robinson, R. J. Riggs, P. E. Coaske,

and W. C. Van Emon, worked entirely in Harding County (see fig. 1) west of R. 8 E., and the other, under the direction of Dean E. Winchester, assisted by E. Russell Lloyd, Carl B. Anderson, and S. D. Greene, examined an area in Perkins and Harding counties east of and including R. 8 E. In 1912 a party under the direction of C. J. Hares, aided by E. G. Woodruff, E. M. Parks, J. B. Reeside, jr., Stuart St. Clair, and Louis R. Roark, and another in charge of E. Russell Lloyd, assisted by Burton W. Clark, W. T. Thom, jr., and L. M. Neuman, spent a portion of the field season in completing the examination of Harding and Perkins counties, respectively.

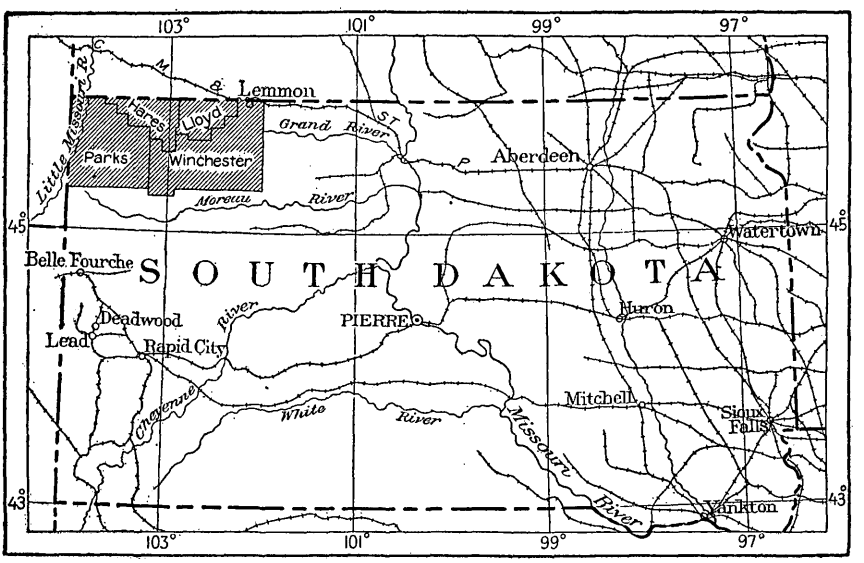


FIGURE 1.—Key map showing area in northwestern South Dakota examined by each field party.

The field work of both seasons was done under the general supervision of M. R. Campbell and E. G. Woodruff, to whom the authors are indebted for many helpful suggestions, both in the field and in the office. Thanks are due also to the many residents of the region for their cooperation and interest in the work.

PREVIOUS WORK.

The first geologist to visit the field was Mr. N. H. Winchell, who accompanied Capt. Ludlow, in 1874, in the military exploration of the Black Hills, and the results of his observations, in the form of an interesting and suggestive journal, are given as a part of the report of the expedition.[1] J. E. Todd, State geologist of South Dakota, in 1893, made a reconnaissance trip into the region to investigate the

[1] Winchell, N. H., Report of a reconnaissance of the Black Hills of Dakota, made in the summer of 1874, by William Ludlow, pp. 21–66, map, 4°, Washington, 1875; U. S. A. Chief of Engineers Rept., 1874, Appendix PP, pp. 1131–1172, Washington, 1875.

lignite, and the data he obtained were published by the South Dakota Geological Survey.[1] Darton[2] has given a summary of the geology of northwestern South Dakota, quoting freely from the reports of Todd and Winchell. Other brief references to this region appear in various reports listed in the bibliography on pages 164–165.

LAND SURVEY.

The area included in the northwestern South Dakota lignite field was surveyed for the General Land Office in the decade 1885–1895. The land corners were marked in some parts of the field by wooden stakes and the regulation pits, but in the greater part by marked stones and pits in place of stakes. Most of the stakes have been destroyed, but the pits and stones remain, so that there is seldom any difficulty in determining the exact location of a corner, except where the markings have been destroyed by roads or cultivation. The surveys of the General Land Office were found to be accurate, so far as could be determined by the methods used in this examination.

FIELD WORK.

The investigation was undertaken primarily to collect data upon which to classify public lands with regard to their mineral or non-mineral character, and it was therefore necessary to locate all data collected with reference to legal subdivisions. In most cases a rapid reconnaissance was first made in each township to determine whether or not lignite was present. During such a reconnaissance the formation boundaries were mapped by plane-table methods or by pacing, and observations were made on the structure and character of the strata. If no lignite beds of sufficient thickness to justify mapping were discovered, further work was not considered necessary. If the preliminary examination revealed lignite beds of importance, they were prospected and measured where possible every thousand feet or so along their outcrop, and the location of such prospects, as well as the position of the outcrop of the beds with reference to section corners, was determined by the use of plane-table methods. Usually in order to make more exact correlations of the scattered exposures, the altitude of each exposure of a lignite bed having a thickness of more than 2 feet was determined by the use of vertical-angle readings in connection with the stadia traverse or single plane-table location. The altitudes of a large number of points along the geologic contacts were also determined, and these were used in interpreting the geologic structure. The altitudes are based on a United States Geological Survey bench mark in T. 12 N., R. 7 E., of the Black Hills meridian;

[1] Todd, J. E., A reconnaissance into northwestern South Dakota: South Dakota Geol. Survey Bull. 2, p. 43, 1898.

[2] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, 1909.

on the altitudes of the Chicago, Milwaukee & St. Paul Railway at Ives, N. Dak., and Lemmon, S. Dak., and on the United Sates Coast and Geodetic Survey's primary bench marks on Table Mountain, Lodgepole Buttes, Slim Buttes, and Short Pine Hills. During the examination a complete map of each township, on a scale of 2 inches to 1 mile, was made and the accompanying maps (Pls. I and II, in pocket) are the result of a compilation of these township maps. The data given on the township plats of the General Land Office were used for platting the land net on plane-table sheets to be used as base maps for the field work.

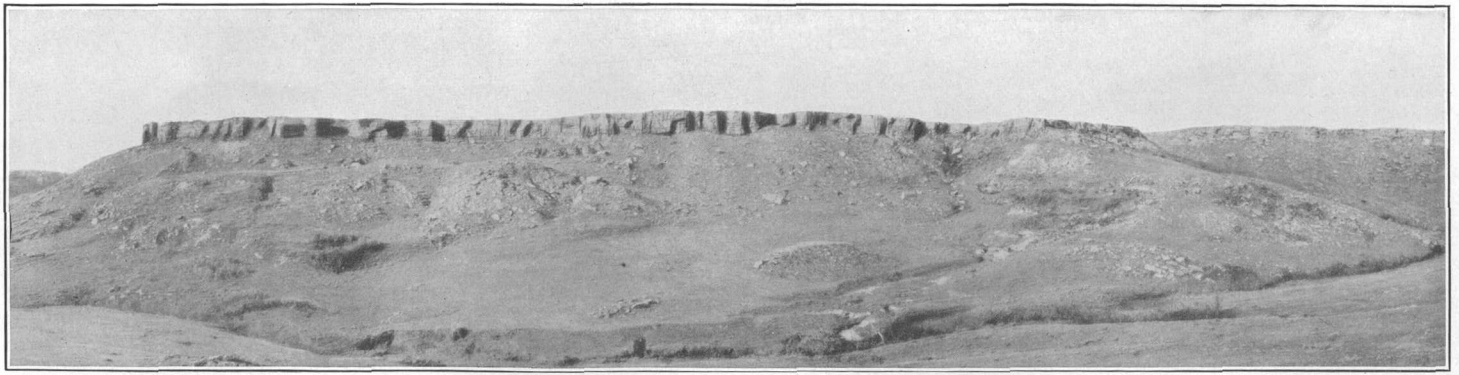
GEOGRAPHY.

SURFACE FEATURES.

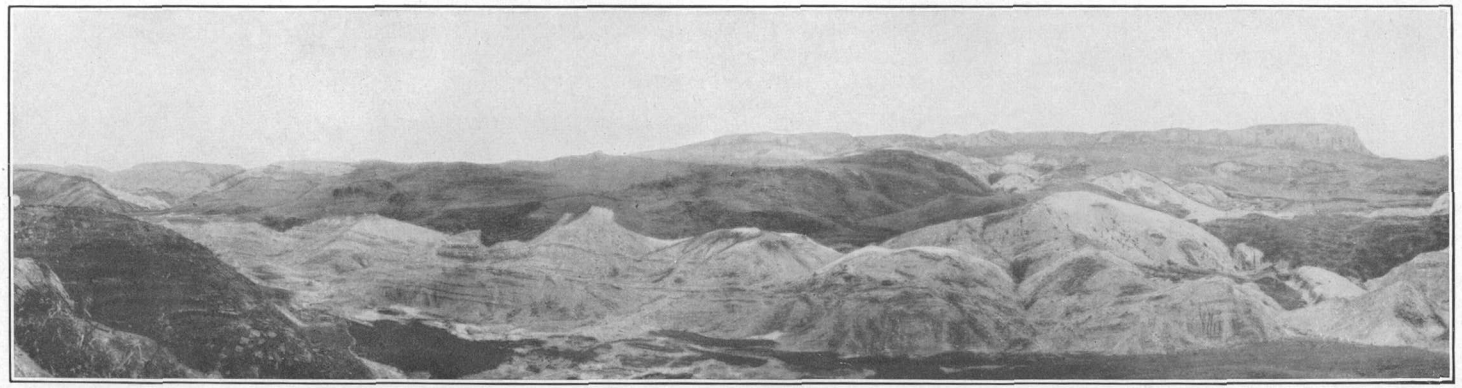
The field described in this report lies in the Great Plains province north of the Black Hills. The region is a rolling, grass-covered prairie, interrupted here and there by small areas of badlands or by steep-sided, flat-topped buttes and ridges. The area south of Grand River and east of the Slim Buttes has long been known to the ranchers of northwestern South Dakota as the "Big Meadow," inasmuch as it has furnished an abundance of hay and excellent grazing for large herds of cattle and horses. Between the northern edge of the Big Meadow and the South Fork of Grand River recent erosion has dissected the area, forming a hilly country known locally as "The Breaks," in which some of the best rock exposures occur. North of the South Fork of Grand River the surface is more undulating but for the most part is covered by grass, so that rock exposures are scarce.

The Slim Buttes, near the center, and the Short Pine Hills, near the southwest corner of the field, are timber-covered mesas rising 300 to 500 feet above the surrounding country. The lower land bordering the cliffs of these buttes has been carved by erosion into intricate badlands with impassable gullies and ridges. The Cave Hills (see Pl. III, *A*), a group of level-topped timbered ridges, small mesas, and disconnected buttes, cover a considerable area in the northern part of the field and are capped by thick beds of yellow and pinkish sandstone which on weathering gives rise to a peculiar honeycomb structure with many small caves. The height of the hills above the general level is 400 to 500 feet. Slumping is much less common than it is about the Slim Buttes and Short Pine Hills.

The red baked rock and clinker resulting from the burning of lignite beds are very resistant and cap sharp cones, buttes, ridges, and small mesas or crop out in low ridges along divides. Their bright colors present a pleasing variation in an otherwise rather dull, monotonous landscape. In northwestern South Dakota clinker



A. WEST FACE OF SOUTH CAVE HILLS, HARDING COUNTY, S. DAK.



B. LANDSLIDE BEDS OF WHITE RIVER FORMATION NORTH OF SLIM BUTTES, HARDING COUNTY, S. DAK.

Thickness of beds included in the slide about 125 feet.

buttes are best developed in the northern part of Harding County, near the Cave Hills, and in Tps. 21 and 22 N., R. 1 E.

Along the small streams, where erosion is so rapid that vegetation can not maintain a foothold, there are many small areas of badlands, where the bare slopes expose all the strata in detail. Such an area, known locally as the "Jump-off," lies along the north side of the divide between Moreau River and the South Fork of Grand River, in Rs. 4 and 5 E., and along the east side of the divide between the Little Missouri and the South Fork of Grand River. It extends from the Short Pine Hills to the south side of T. 20 N., R. 3 E., where it gradually gives way to a rolling prairie. The "Jump-off" badland ranges in width from half a mile to 3 miles and forms a marked contrast with the slopes on the south and west sides of the divide.

Locally there are areas of sand dunes, particularly between the South Fork of Grand River and the East Short Pine Hills.

The altitude of the field ranges from about 2,100 feet above sea level in the valley of Grand River, at the east border of the field, to 3,607 feet on Table Mountain, 3,222 feet on the Lodgepole Buttes, 3,624 feet on the Slim Buttes, and 4,019 feet on the West Short Pine Hills, giving a maximum relief of about 1,900 feet.

DRAINAGE AND WATER SUPPLY.

Three large streams receive the drainage from this field—Little Missouri, Grand, and Moreau rivers.

Little Missouri River, which enters the field from the southwest, flows northward across the western part of Harding County, receiving the drainage of a strip of country about 12 miles in width. Its principal tributaries are Valley and Big Boxelder creeks. The river contains running water at all times, although in dry years the flow is very small. Its valley is broad and open, and the stream meanders over a flood plain about a mile in width.

The South Fork of Grand River is formed by the confluence within a short distance of six perennial streams—Bull, Jones, Buffalo, Sand, Squaw, and Big Nasty creeks. In the eastern part of the area it is joined by the North Fork of Grand River. Its flow is generally less than that of Little Missouri River, but it is scarcely ever dry. In Perkins County the river occupies a broad, open valley cut from 300 to 400 feet below the average level of the Big Meadow to the south, and its many tributaries, which enter at nearly right angles, occupy narrow, steep-sided valleys. Near the river itself are low, sandy hills and broad, sandy flats, whereas away from the stream, in eastern Harding and Perkins counties, the divides are in many places capped by small rocky buttes.

Moreau River, through its tributaries, Antelope, Rabbit, and Thunder Butte creeks, drains most of the Big Meadow and a large

area southwest of the Slim Buttes. The North Fork of Moreau River rises in the southwestern part of the field, but east of range 8 its course is wholly outside of the area.

The many small streams tributary to the Little Missouri and to the South Fork of Grand River have a tendency to flow in northwest or southeast directions. This trend of stream courses is markedly parallel to the strike of the rocks and may have been determined by the rock structure. All the perennial streams and many of the intermittent streams meander on scales commensurate with their size, many of them with almost diagrammatic regularity.

The waters that flow eastward in western South Dakota have a much shorter course to the Gulf of Mexico than those which flow by way of Little Missouri River; in fact, the distance from western Harding County down Little Missouri and Missouri rivers to Fort Pierre, S. Dak., is nearly twice as great as the distance by way of Grand River. This difference produces a much steeper gradient and much more active erosion in the valleys of the eastward-flowing streams. The bed of the South Fork of Grand River at Buffalo is nearly a hundred feet lower than that of Little Missouri River at Camp Crook, about 12 miles to the west, although the latter is a much larger stream. Doubtless if conditions remain as they are at present Little Missouri River will in time be captured by Grand River, as its headwaters 50 miles above have been captured by Belle Fourche River.[1] Erosion at the head of one of the eastward-flowing tributaries of the South Fork of Grand River may in time cut through the present divide between the two rivers and make this capture possible. The waters of the Little Missouri will then flow along what is now Valley Creek for a distance of 3 or 4 miles and cut across the present divide in a general eastward direction, joining the south fork of Grand River near Buffalo.

Throughout the field water for domestic use and for stock is obtained chiefly from shallow wells, although there are a number of good springs. In the open plains area springs are scarce, and the water, which in most places issues from lignite beds, is not especially good. Along the margin of the Slim Buttes, however, there are a number of good springs which issue near the base of the White River formation. The best known of these springs is near the old L ranch, in sec. 29, T. 18 N., R. 8 E., where an abundant supply of pure, cool water flows from a sandy shale near the base of the buttes. Other good springs, issuing from about the same horizon, have been known and used by the stock ranchers for many years. In Cave Hills and Lodgepole Buttes are good springs which also have had an

[1] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, p. 189, 1905.

important part in the stock-raising history of the country. No artesian water has been developed, and in general the prospect of developing artesian water in the field is not good, as the sandstones are not persistent over sufficiently large areas. According to Darton[1] the head of water from the sandstones of the Benton shale or from the Dakota sandstone, which are the main water-bearing formations of the Black Hills, would be insufficient to produce a flowing well in this area. A well in the Little Missouri flat at Camp Crook was drilled to a depth of 1,100 feet and no flow of water was obtained. At this place the Pierre shale is within 100 feet of the surface, and it is probable that this well did not reach the water-bearing formations or even go completely through the Pierre shale. No water could be expected before the Pierre is passed through, which would mean a depth of 1,400 to 1,700 feet at Camp Crook.

Some of the flats along the larger streams are irrigated by damming smaller tributary valleys to catch the spring wash, and at Willett water is pumped from the river to the terrace by steam power. Both methods are found profitable and may become more profitable with improved appliances.

CLIMATE AND VEGETATION.

Perkins and Harding counties are located in the semiarid area of the Great Plains, where the annual rainfall is about 15 inches and this often falls at seasons when it is least needed. During several years previous to 1910 the rainfall was sufficient to produce an abundant growth of vegetation over a large part of the Big Meadow, and the native grass is reported to have stood knee-high in many places. A large part of the area was originally an open prairie and is destitute of trees, except for a few willows and cottonwoods along stream courses and pines on the buttes. Most of the land can be cultivated and by the use of proper methods of cultivation should yield good crops. The soil constituents are such that only a small amount of moisture is necessary to raise potatoes and other garden vegetables, as well as certain small grains. Not infrequently promising fields of grain are parched in a few days by dry winds or beaten down by hailstorms.

The Slim Buttes, Short Pine Hills, and Cave Hills are included in the Sioux National Forest and are clothed with a scanty growth of yellow pine (*Pinus ponderosa*) and cedar. The pines are far larger and more abundant than the cedars. At present only dead timber may be removed from the national forest, and this only by permission of the forest ranger.

[1] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, p. 77, 1909.

SETTLEMENT.

Several large cattle and horse ranches were established in the area in the early eighties, but recently most of them have given way to small farms. Since 1908 the field has been settled rapidly, so that in 1912 there were very few sections of land that had not been entered by the homesteader.

Lemmon, on the Chicago, Milwaukee & St. Paul Railway, is the largest town in the area, having, according to the last census, a population of 1,200, and is a distributing point for a large section of the surrounding country. Meadow, one of the older towns of the region, is the distributing point for mail for the near-by towns and is connected with Lemmon by a daily automobile stage. Bison, the county seat of Perkins County, is a town of about 100 inhabitants in sec. 13, T. 18 N., R. 13 E., and is connected with the railway at Lemmon by daily stage going through Meadow. Strool, in sec. 19, T. 18 N., R. 11 E., a thriving business town of about 75 inhabitants, is the distributing center for a large area and is connected with Hettinger, N. Dak., by daily automobile stage. Camp Crook, with 125 inhabitants, is located on Little Missouri River 6 miles north of the West Shore Pine Hills, and is on a stage line between Belle Fourche, S. Dak., on the Chicago & North Western Railway, and Bowman, N. Dak., on the Chicago, Milwaukee & St. Paul Railway. Buffalo, the county seat of Harding County, in sec. 30, T. 19 N., R. 5 E., has a population of about 100 and is on another stage line connecting Belle Fourche and Bowman. Each of the remaining places indicated on the maps (Pls. I and II, in pocket) consists of a few houses with a store or two and a post office, or of a ranch house that serves as a post office.

In addition to the main stage roads, there are numerous other roads which give easy access to all parts of the field except those immediately adjacent to the high mesas. Roads are being rapidly adjusted to section and township lines, and it was not deemed advisable to show their present locations on the map. The Chicago, Milwaukee & St. Paul Railway, the only railway which enters the field, crosses only the northeastern corner. During 1910 a survey was made for an extension of a branch line of this road from Isabel and Firesteel, east of the field, across Perkins County near Chance, Daviston, and Sorum. No construction work, however, has yet been done on this line.

GEOLOGY.

GENERAL OUTLINE.

The stratigraphic section exposed in the northwestern South Dakota lignite field includes rocks of Cretaceous, Tertiary, and Quaternary age. The oldest rocks belong to the upper part of the Pierre shale, which

is of marine origin, and are succeeded by the Fox Hills sandstone, also marine. This is in turn overlain by the predominantly fresh-water shale and sandstone of the Lance formation.

In the field two members of the Lance formation are recognized in addition to a lower undifferentiated part. The upper one is the Cannonball marine member, of which, however, the distribution in northwestern South Dakota is not definitely known. It is known to extend across the northern part of Perkins County and at least a part of Harding County. The type locality of the member is on Cannonball River in Morton County, N. Dak., and the member has been described by Lloyd[1] and later by Lloyd and Hares.[2]

In the western part of the field the Ludlow lignitic member underlies the Cannonball and is typically developed in the vicinity of Ludlow, Harding County. In the eastern part of the field the Ludlow member is thinner and the Cannonball thicker, and the two are therefore probably in part of the same age. The authors' interpretation of the conditions of sedimentation is illustrated by the accompanying diagram (fig. 2).

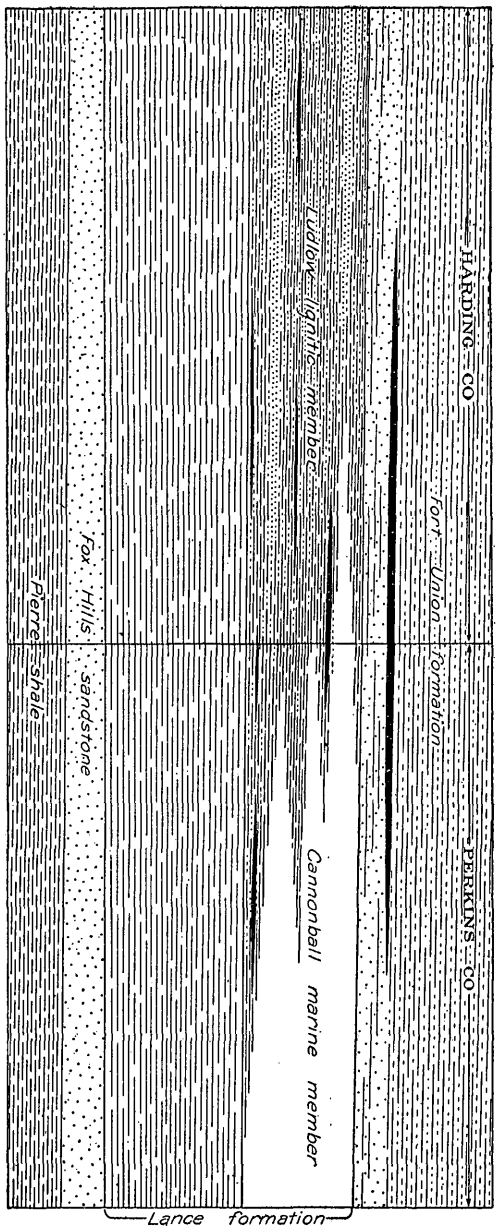


FIGURE 2.—Diagram showing the interrelation of the members of the Lance formation.

[1] Lloyd, E. R., The Cannonball River lignite field, N. Dak.: U. S. Geol. Survey Bull. 541, pp. 243–291, 1914.

[2] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523–547, 1915.

The predominantly light-colored sandstone and shale of the lignite-bearing Fort Union formation overlie the Lance and are apparently conformable with it. Rocks of Oligocene and possibly Miocene age form a number of prominent buttes and rest unconformably on both the Lance and Fort Union formations. Quaternary deposits are represented by dune sands, by the present flood plains of the principal streams, and by old river terraces from 50 to 75 feet above the present valley floors.

A general geologic section is given below.

Generalized section of the geologic formations in northwestern South Dakota.

System.	Series.	Formation and member.	Thickness in feet.	Character.
Quaternary.				Sand dunes, terrace and flood-plain deposits.
Tertiary.	Miocene (?).	Arikaree (?) sandstone.	75–225	Thick-bedded gray to greenish-white calcareous sandstone, generally fine grained. Contains many fragments of acidic volcanic rocks. Weathered surface in places shows concretionary structure.
		Unconformity(?)		
	Oligocene.	White River formation, including both Titanotherium and Oreodon zones.	45–140	Banded and flesh-colored calcareous clays, with siliceous nodules and irregular plates in upper half and coarse white calcareous sandstone in lower half. Locally cross-bedded on large scale.
	Unconformity, both angular and erosional. At least 750 feet of rock strata removed.			
	Eocene.	Fort Union formation.	425	Massive fine-grained yellow sandstone, shale, and lignite.
Tertiary(?)	Eocene (?).	Lance formation. Cannonball marine member.	0–225	Dark fine-grained sandstone and shale.
		Ludlow lignitic member.	0–350	Yellowish to gray sandstone, clayey sandstone, shale, and lignite beds, variable in thickness and quality.
			425	Somber-colored soft shale, brown shale, and gray sandstone, with thin lignite lenses in upper part. Lower half more sandy and contains few lignite or bituminous bands. Many concretions and thin lenses of iron carbonate. Loglike concretions. Extremely variable throughout.
Cretaceous.	Upper Cretaceous.	Fox Hills sandstone.	25– 75	Marine grayish-white to yellowish friable sandstone, with concretions.
		Pierre shale.	50 exposed.	Marine dark shale containing oval limestone concretions that break into rhombs when exposed to weather. Gives rise to gumbo soil.

CRETACEOUS SYSTEM.

PIERRE SHALE.

The Pierre shale crops out in a small area near the extreme southwest corner of the field, where only about 50 feet of the formation is exposed. According to Darton,[1] its total thickness in this region is 1,200 to 1,400 feet. The record of a well at Camp Crook shows that the Pierre is within 100 feet of the surface at that place.

The formation is made up of drab to black soft, crumbly shale, which is very fine grained and apparently homogeneous throughout, with the exception of scattered concretions, which are nonfossiliferous. The cone-in-cone structure is common in most exposures. Gypsum is abundant, occurring as small crystals in the shale, and is the cause of much of the alkali in the water flowing over this formation. The weathered outcrops of the formation are ashen, tan, or light brown in color and extremely porous, but in fresh outcrops along stream channels the shale appears nearly black and is so soft that it may be easily carved into blocks with a knife. Structurally it is thinly bedded and jointed.

The Pierre shale weathers into a somewhat barren rolling and uninviting country, commonly known as the "gumbo country." Its areas are distinguished topographically by smooth, rounded hills, gentle slopes and valleys, and a general absence of peculiar erosion forms such as characterize areas of the Lance formation. The soil when dry is loose and often deeply cracked, but when wet it is very sticky and boggy. For agricultural purposes soil derived wholly from the Pierre is very poor, being usually alkaline and infertile. Such vegetation as grows on it appears to be stunted, and much of the ground is barren.

No fossils were collected from the Pierre in the area covered by this report, but elsewhere it carries a large marine fauna, as cited by Darton.[2] Calvert,[3] Leonard,[4] and others.

FOX HILLS SANDSTONE.

The Fox Hills sandstone overlies the Pierre shale south of the Short Pine Hills and is exposed along the axis of the low Glendive anticline along the North Dakota State line east of Little Missouri River. South of the Short Pine Hills the formation consists of 25 feet or more of very friable yellow to gray medium-grained sandstone, with concretions showing cross-bedding. The upper limit of the

[1] Darton, N. H., op. cit., p. 23.

[2] Idem, p. 41.

[3] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 192-194, 1912.

[4] Leonard, A. G., The geological history of North Dakota: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 227-243, 1908.

formation can not be ascertained with accuracy in this part of the field, owing to the grass-covered character of the country.

In the area along the North Dakota State line only 30 or 40 feet of the formation is exposed and the upper limit is fairly distinct. The formation consists of very light gray or almost white sandstone, composed of rather fine grains of white quartz and a small amount of black mica, the whole weakly cemented by calcium carbonate. This area is at the south end of the Glendive anticline, and the sandstone has been included in the Colgate sandstone member of the Lance formation, as mapped around the same anticline farther northwest.[1] Shark teeth and the marine plant *Halymenites major* occur abundantly in the formation in North Dakota.[2] Fossil leaves were collected in T. 23 N., R. 2 E., from ferruginous concretions on the surface of the formation, but these concretions may have been washed down from the overlying Lance.

Although the Fox Hills is only 25 to 75 feet thick in this area and is 300 to 400 feet thick in the type locality at Fox Ridge, S. Dak., 200 miles to the east, the difference may be due to unequal deposition and not to unequal erosion, as the sandstone represents a shore phase of deposition.

It does not appear that in this region there was any profound break in sedimentation, either at the beginning or at the end of Fox Hills time. The exposures are so poor as to preclude the detection of discordance of strikes and dips or evidence of erosional unconformity, but if there was a hiatus, it was one in which little or no erosion occurred.

The sandstone is assigned to the Fox Hills formation on the grounds that in this field, as in the type locality about 200 miles to the east, the Fox Hills occurs conformably immediately above the Pierre; lithologically it is similar to the Fox Hills in its type area; and the formation in North Dakota, with which this area is directly connected, bears marine fossils (shark teeth and *Halymenites major*) and a few Cretaceous invertebrates.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

GENERAL CHARACTER.

The Lance formation, so far as observed, rests conformably on the Fox Hills sandstone. The beds of both formations lie almost horizontal and no discordance of dip and strike is noticeable. The Lance consists of three parts: (1) A lower part lithologically and faunally similar to the Lance in other fields near by; (2) the Lud-

[1] Calvert, W. R., op. cit., pp. 189, 194–195.

[2] Hares, C. J., Lignite in southwestern North Dakota: U. S. Geol. Survey Bull. (in preparation).

low lignitic member, 0 to 350 feet thick, lithologically and florally similar to the Fort Union; and (3) the Cannonball marine member, 0 to 225 feet thick. Figure 2 (p. 15) shows the relations of these divisions of the Lance to one another and to the Fox Hills and Fort Union formations. The three parts of the formation are variable in character, and the change from the prevailing somber shale of the lower part to the more yellow sandstone or sandy shale of the Ludlow member is well defined in some parts of the field and gradual in others.

The lower part of the Lance weathers into badlands and into rounded buttes and ridges, whereas the weathering of the Ludlow member produces flat-topped buttes capped by sandstone.

LOWER PART OF THE LANCE FORMATION.

The lower part of the Lance is the surface formation over a very large part of the field. It occupies practically the whole of Harding County south and west of the Slim Buttes, Cave Hills, and Table Mountain, with the exception of the Short Pine Hills and the small areas of Pierre shale and Fox Hills sandstone. In Perkins County it outcrops in a broad zone along the south and east margins of the field and is exposed along the valley of the South Fork of Grand River.

The maximum thickness (about 425 feet) of the lower part of the Lance occurs south of the Slim Buttes, in Tps. 15 and 16 N., R. 8 E. This part of the formation consists predominantly of somber-colored sandy shale, but contains local lenses of fine-grained gray and yellow sandstone and thin beds of lignite of varying quality. Iron carbonate, which weathers to limonite, occurs in the shale as concretions and as thin lenses. The yellow sandstone contains marcasite concretions and "log concretions."

The upper limit of the lower part of the Lance is placed at the horizon where the prevailingly somber-colored shale is succeeded by the prevailingly yellow sandy strata. The horizon is in many places marked by a bed of lignite. That part of the formation lying below the horizon as a rule is nonlignitic and all the dinosaur remains collected during the field examination were found in it.

The lower part of the division as a whole is barren of economically important lignite beds and contains very little, if any, rock suitable for building stone. Near the top of this division several small and for the most part thin lenses of lignite were found, one of which is more than 4 feet thick over a considerable area in T. 21 N., R. 5 E.

LUDLOW LIGNITIC MEMBER.

Rocks assigned to the Ludlow lignitic member of the Lance formation occur in the western part of the field, as outliers, as a thin covering of the divides, and as belts around the higher buttes and mesas.

In the eastern part they underlie large areas along the divide between Moreau River and the South Fork of Grand River, and from the latter stream northward to the State line.

The Ludlow lignitic member is named from the town of Ludlow, in Harding County, where it is well exposed. Its thickness in this part of the field is from 300 to 350 feet, but it is thinner toward the east and has not been recognized east of the field. The Ludlow member is distinguished from the underlying Triceratops-bearing portion of the Lance by a generally lighter color and a greater amount of sandstone and lignite. Lithologically it is very similar to the Fort Union formation, but it is separated from that formation throughout at least a part of the field by the marine Cannonball member.

The Ludlow lignitic member, in its type locality, consists of interbedded light-colored sandstone and shale of varying composition and lignite. There are all gradations between a true shale and a quartz sandstone. As in the lower part of the Lance, by far the greater proportion of the rock is loosely consolidated and easily disintegrated. The following stratigraphic sections show the character of the Ludlow member fairly well:

Composite sections of part of the Ludlow lignitic member of the Lance formation.

Section in secs. 32 and 36, T. 22 N., R. 5 E.

	Ft.	in.
Top of mesa.		
Sandstone, yellowish, and shale (Fort Union formation)	255	0
Lignite		8
Sandstone, somewhat shaly	45	0
Shale, dark	2	0
Lignite	2	4
Sandstone, light colored, grayish, argillaceous	12	0
Sandstone, buff with ferruginous specks	15	0
Lignite		2
Sandstone, buff, fine grained, muscovitic	11	0
Lignite		3
Sandstone	8	0
Lignite		6
Sandstone, buff	25	0
Shale, bluish	1	0
Shale, carbonaceous		10
Shale, arenaceous	5	0
Lignite		1
Sandstone, buff, soft	5	4
Sandstone	1	0
Shale, arenaceous, with carbonaceous streaks	4	0
Sandstone, argillaceous	6	0
Lignite	1	0
Concealed	22	0
Sandstone, drab, cross-bedded, ripple-marked	3	0
Shale, arenaceous	4	0
Lignite	1	5

Composite sections of part of the Ludlow lignitic member of the Lance formation—Con.

Section in secs. 32 and 36, T. 22 N., R. 5 E.—Continued.

	Ft.	in.
Shale, brown	3	0
Lignite	2	1
Shale, dark		5
Lignite		8
Shale	1	3
Lignite	1	5
Shale, brown	4	0
Lignite	2	3
	191	8

Section in T. 20 N., R. 9 E.

Sandstone, yellow, medium fine grained, capping hills	20	0
Shale, brown	3	0
Lignite	1	0
Shale, brown		6
Sandstone, yellow	16	0
Shale, brown	1	10
Lignite, dirty		8
Shale, brown	3	0
Shale, black		8
Lignite, dirty		6
Shale, brown	1	6
Sandstone, buff to yellow	12	0
Shale, brown	2	0
Shale, black		4
Lignite		8
Sandstone and shale, with lignite streaks	13	6
Lignite		8
Shale		3
Lignite	3	6
Shale, brown, arenaceous	1	0
Sandstone.		
	82	7

Section in T. 21 N., R. 7 E.

Top of "Two Tops."		
Sandstone and shale (Fort Union formation)	138	0
Shale, chocolate-colored	2	0
Sandstone, buff and yellow, fine grained, alternating with buff shale	9	0
Shale, chocolate-colored	3	4
Lignite	1	0
Shale, buff and yellow sandstone, alternating	16	0
Shale, chocolate-colored	3	0
Sandstone, brown, fine grained	2	6
Shale	10	0
Lignite, Giannonatti bed	11	8
Sandstone, light, argillaceous	16	4
Shale, brown	3	0
Lignite	4	2

Composite sections of part of the Ludlow lignitic member of the Lance formation—Con.

Section in T. 21 N., R. 7 E.—Continued.

	Ft.	in.
Shale	13	0
Lignite	3	8
Shale and sandstone	15	0
Lignite	3	4
Shale, carbonaceous		6
Shale.		
	117	6

Section in sec. 36, T. 21 N., R. 6 E.

		Ft.	in.
Sandstone, light buff, fine grained		16	0
Lignite	Giannonatti bed	3	10
Shale			2
Lignite		5	4
Shale, brown			3
Lignite		1	6
Shale, brown		10	0
Lignite			10
Sandstone ?, mostly concealed		42	0
Shale		15	0
Lignite, Widow Clark bed		4	1
Shale, brown		6	0
Sandstone and shale		25	0
Lignite		1	0
Shale		5	0
Lignite, dirty		2	6
		138	6

Lignite beds occur throughout the Ludlow member, but few of them are persistent for more than a few miles along their outcrop. Locally they attain considerable thickness and have been worked to supply a large part of the fuel for the inhabitants of the region. A very large proportion of the lignite in the South Dakota field occurs in the Ludlow member. The thickest and most extensive beds or groups of beds is the T Cross, which occurs near the top of the member, and the Widow Clark.

In the northeastern part of Harding County many stone houses are built of thin, flaggy sandstone from the Ludlow lignitic member of the Lance formation.

CANNONBALL MARINE MEMBER.[1]

The Cannonball marine member of the Lance formation comprises the sediments deposited in the sea which extended over a portion of North and South Dakota after the deposition of the underlying sediments of continental origin. The type locality for this member is on Cannonball River in Morton County, N. Dak., where from 300 to 350 feet of marine beds are exposed. In South Dakota the marine

[1] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation in North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523–547, 1915.

member has been recognized in a comparatively narrow zone surrounding the areas of Fort Union rocks in northern Perkins County and in northeastern Harding County. The geographic distribution of the member is not definitely known, for the reason that it is defined almost wholly by its contained fossil fauna and the fossils were found only near the end of the work in the general region of northwestern South Dakota and the limits of the member had not previously been mapped. The limits as shown on Plates I and II (in pocket) were drawn from the known position of lignite beds and from the topography and are only approximate. This member becomes gradually thinner toward the west and has not been recognized west of R. 9 E. The presence of a brackish-water fauna at about the same stratigraphic horizon on Little Missouri River near Yule, N. Dak., however, suggests that the marine sediments extend farther west in North Dakota than in this field.

The only place in northwestern South Dakota where the Cannonball member was examined in detail is near Bloom post office, in T. 23 N., R. 9 E. The following section shows the character of the member and associated beds at this place:

Generalized section in vicinity of Bloom, S. Dak., T. 23 N., R. 9 E.

	Top.	Ft.	in
9.	Sandstone, brown and yellow, fine grained, thin bedded, interbedded with lenses of compact bluish-gray limestone	30	0
8.	Sandstone, dark gray, calcareous, marine (fossil collections Nos. 43 and 44)	10	0
7.	Shale	1	0
6.	Lignite	2	0
5.	Shale and sandstone interbedded; sandstone in lower part light brown, medium fine grained, micaceous, marine (fossil collection No. 45)	40	0
4.	Lignite	1	0
3.	Shale	4	0
2.	Lignite	2	3
1.	Shale.		
	River.	90	3

The beds numbered 5, 8, and probably 9 of the above section belong to the Cannonball member. In addition to the collections of marine fossils mentioned in the section, a few more were obtained in northern Perkins County from the residual bowlders of thin but persistent beds of concretionary limestone.

FOSSILS.

During the two field seasons several small collections of fossils were made in different parts of the field and at different horizons. The plant remains have been studied by F. H. Knowlton, the invertebrates by T. W. Stanton, and the vertebrates by J. W. Gidley.

The following lists show the localities at which the collections were made and the fossils identified from each collection:

Fossils collected from the lower part of the Lance formation.

F 23.[1] NE. ¼ sec. 3, T. 19 N., R. 7 E.
Carpites sp.
Sequoia nordenskioldi (?) Heer.
Nelumbo n. sp.

F 24. NW. ¼ sec. 3, T. 19 N., R. 7 E.
Sequoia nordenskioldi Heer.
Sapindus affinis Newberry.

F 6. SW. ¼ SE. ¼ sec. 33, T. 22 N., R. 3 E.
Ficus ungeri? Heer.

F 55. Sec. 17, T. 21 N., R. 16 E.
Populus cuneata Newberry.
Populus amblyrhyncha Ward.
Celastrus pterospermoides Ward.

F 47. Sec. 7, T. 17 N., R. 11 E. (from roof of Phillips lignite mine).
Grewia celastroides Ward.
Celastrus pterospermoides Ward.
Stems, etc.

F 16. NW. ¼ sec. 2, T. 18 N., R. 5 E.
Triceratops, fragment of skull.
Trachodon.

F 11. NE. ¼ sec. 2, T. 19 N., R. 4 E.
Trachodon, caudal and foot bone, vertebræ.
Aspideretes, costal bone.
Champsosaurus, vertebræ.
Compsemys?
Basilemys?

F. 10. Center of sec. 20, T. 17 N., R. 4 E.
Aspideretes.
Champsosaurus.

F 7. SW. ¼ sec. 26, T. 17 N., R. 3 E.
Champsosaurus.
Leidyosuchus.
Triceratops.
Trachodon.
Compsemys.
Aspideretes.

F 8. Center of sec. 36, T. 17 N., R. 3 E.
Champsosaurus.
Leidyosuchus.
Aspideretes.
Compsemys.
Basilemys.
Trachodon.
Ceratopsian.
Lepisosteus.
Triceratops.

F 9. NE. ¼ NW. ¼ sec. 23, T. 16 N., R. 3 E.
Aspideretes.
Champsosaurus.
Trachodon.

F 38. NW. ¼ sec. 8, T. 15 N., R. 9 E.
Aspideretes.

F 54. Sec. 13, T. 20 N., R. 16 E.
Champsosaurus.
Ornithomimus.

F 5. SW. ¼ NE. ¼ sec. 30, T. 23 N., R. 2 E.
Ornithomimus.
Trachodon.
Champsosaurus.
Aspideretes.

Fossils collected from the Ludlow lignitic member of the Lance formation.

F 28. Sec. 32, T. 18 N., R. 8 E. (from soft shaly sandstone above a lignite bed and about 225 feet above the base of the Ludlow member).
Taxodium occidentale Newberry.
Ginkgo adiantoides? Heer.
Sapindus affinis? Newberry.
Fragmentary leaf.

F 40. Sec. 24, T. 17 N., R. 9 E. (from yellow friable sandstone above a lignite bed near the head of Wolf Draw, about 90 feet above the base of the Ludlow member).
Platanus haydenii Newberry.
Populus amblyrhyncha Ward.
Populus daphnogenoides Ward.
Viburnum sp.

F 50. Sec. 29, T. 17 N., R. 13 E. (from baked shale above lignite bed which occurs at base of Ludlow member).
Carpites sp.
Sapindus affinis? Newberry.
Fern, fragmentary.
Corylus sp.
Celastrus sp.?
Cocculus haydenianus Ward.

F 51. Sec. 17, T. 17 N., R. 13 E. (from shale above lignite at Sexton mine).
Onoclea sensibilis Linné.
Cocculus haydenianus Ward.
Sapindus cf. S. affinis Newberry.
Sapindus grandifoliolus Ward.
Conifer, Taxodium ? sp.

[1] Numbers refer to location numbers on maps.

Fossils collected from the Ludlow lignitic member of the Lance formation—Continued.

F 18. NE. ¼ SW. ¼ sec. 12, T. 17 N., R. 7 E.
Sequoia nordenskioldi Heer.
Thuya interrupta Linné.
Cocculus haydenianus Ward.
Viburnum sp.
Populus cuneata Newberry.
Populus.
Celastrus pterospermoides Ward.

F 19. Center of sec. 1, T. 17 N., R. 7 E.
Thuya interrupta Newberry.

F 20. NE. ¼ SE. ¼ sec. 36, T. 18 N., R. 7 E.
Thuya interrupta Newberry.
Onoclea sensibilis Linné.
Viburnum cf. V. elongatum Ward.
Leguminosites arachioides Lesquereux.

F 22. SW. ¼ SW. ¼ sec. 24, T. 19 N., R. 7 E.
Sequoia nordenskioldi Heer.
Sapindus grandifoliolus Ward.
Celastrus pterospermoides Ward.
Celastrus curvinervis Ward.

F 14. SE. ¼ SE. ¼ sec. 5, T. 20 N., R. 5 E.
Sequoia nordenskioldi Heer.
Sapindus sp.

F 46. NW. ¼ SE. ¼ sec. 32, T. 21 N., R. 10 E.
Taxodium occidentalis Newberry?
Fragments of plant stems.

F 12. Center of sec. 7, T. 22 N., R. 4 E.
Centrum of vertebra and other fragments of a crocodile of Tertiary aspect. Not determinable.

Fossils collected from the Cannonball marine member of the Lance formation.

F 41. SE. ¼ sec. 14, T. 21 N., R. 9 W.
Ostrea glabra M. and H.

F 43. Sec. 36, T. 23 N., R. 9 W.
Fossil wood full of burrows of Teredo-like shell.

F 44. Sec. 24, T. 23 N., R. 9 W., a quarter of a mile from Bloom, on the south bank of the North Fork of Grand River.
Nucula sp.
Callista deweyi M. and H.
Pholos sp.
Corbula sp.
Anchura americana E. and S.

F 56. SW. ¼ sec. 11, T. 21 N., R. 14 E., on North Fork of Grand River, 10 miles south of White Buttes, S. Dak.
Small specimens of Nucula, Crenella, and other small marine pelecypods.

F 57. SW. ¼ sec. 2, T. 22 N., R. 12 E.
Anchura americana (E. and S.).

F 58. West quarter corner of sec. 11, T. 22 N., R. 15 E., 7 miles southwest of Lemmon, S. Dak.
Nucula planimarginata M. and H.
Thracia aff. I. subgracilis Whitfield.
Lunatia sp.
Anchura americana (E. and S.).

F 59. East side of sec. 7, T. 22 N., R. 17 E., 8 miles southeast of Lemmon, S. Dak.
Nucula planimarginata M. and H.
Leda scitula M. and H.?
Veniella? sp.
Tellina? sp.
Corbula? sp.
Thracia? sp.
Anchura americana (E. and S.).
Fasciolaria (Piestocheilus) culbertsoni M. and H. var.
Cylichna? sp.

F 60. SW. ¼ sec. 34, T. 23 N., R. 17 E., 9 miles east of Lemmon, S. Dak.
Nucula planimarginata M. and H.
Anchura americana E. and S.
Turris aff. T. contortus M. and H.
Fragment of crustacean claw.

The evidence of the fauna and flora listed above is somewhat at variance. The flora throughout, according to Knowlton, is Tertiary in aspect and is so much like that of the succeeding Fort Union formation that at present it is impossible to separate the two formations on the basis of fossil leaves. Certain species, however, have been found only in the Lance formation. The flora is distinct from

that found in rocks of recognized Cretaceous age of the Rocky Mountain region, although there are many forms in common.

Some of the fresh-water invertebrates found in adjacent areas[1] are not distinguishable from those found in the overlying Fort Union, and the fresh-water fauna is therefore of little value in determining the age of the Lance. The marine invertebrate fauna, which is confined to the Cannonball member, is very similar to but not identical with the fauna of the Fox Hills sandstone, of recognized Cretaceous age. This fauna is so like that of the Fox Hills that the open sea in which the Fox Hills sediments were deposited must have persisted in no very remote area throughout the time when the lower part of the Lance was being laid down in fresh water. No marine invertebrate fossils have been found in the Fort Union or later formations in this part of the United States, and the value of this fauna in determining the Cretaceous age of the Lance is doubted by many geologists.

The reptilian remains, which were collected almost wholly from the lower part of the formation, are forms that are common to the Lance of other areas. The chief diagnostic fossil, Triceratops, is present in this field, and representatives of the family Ceratopsidæ, to which it belongs, have been found in rocks varying in age from about the middle of the Upper Cretaceous to the end of the Lance epoch, but not in strata of later age.

It is also impossible to settle the question as to the Tertiary or Cretaceous age of the Lance on the basis of evidence of diastrophism. Some evidence of unconformity at the base of the Lance has been observed at a number of places in the Dakotas and in eastern Montana, but the writers do not believe that these unconformities indicate a marked break in sedimentation.

On careful consideration of all the evidence available at the present time the United States Geological Survey has decided to consider the Lance as of Tertiary (?) age.[2]

TERTIARY SYSTEM.

FORT UNION FORMATION (EOCENE).

Rocks of Fort Union age are found mainly north of Big Nasty Creek and the South Fork of Grand River, in the northern three tiers of townships extending from the northeast corner of the field to Table Mountain. Remnants of the formation caps Table Mountain, the Cave Hills, Eagles Nest, and Two Tops Butte and cover other isolated areas.

[1] Hares, C. J., Lignite in southwestern North Dakota: U. S. Geol. Survey Bull. (in preparation).

[2] The writers, however, are divided in their opinions. Hares and Lloyd are convinced that the Lance is of Cretaceous age; Winchester is equally convinced that it is of Tertiary age. Winchester is of the opinion that the fossil flora presents the most complete and therefore most reliable evidence, inasmuch as leaves are found in Cretaceous as well as Tertiary rocks, and there is a marked difference between the flora of the Lance and Fort Union and that of recognized Cretaceous formations. Hares and Lloyd, on the contrary, are of the opinion that greater weight should be given to the evidence furnished by the marine fauna and the land vertebrates.

The Fort Union formation, which overlies the Lance, is about 300 feet thick, as determined in the southeastern part of T. 22 N., R. 8 E., where the highest Fort Union sediments in the field cap the Lodgepole Buttes. This, however, is probably only a small part of the original thickness of the formation, which at one time probably extended over the entire region.

The rocks, which vary in color from light gray, tan, and buff to brown, are chiefly arenaceous in composition. They are in places argillaceous or carbonaceous and here and there highly calcareous. Nearly all the sediments are partly cemented by calcium carbonate and effervesce freely with weak hydrochloric acid. They are for the most part very fine grained and evenly thin bedded, though in places rather massive.

The basal sandstone of the Fort Union caps the Cave Hills, Eagles Nest, in T. 23 N., R. 5 E., and Table Mountain, the culminating point on the divide between the North and South forks of Grand River and Little Missouri River. To the east it loses its massive character and seem not to be present in the Tepee Buttes or in the butte northwest of Ludlow. The sandstone in places resists erosion to a marked extent and stands out in vertical walls, to which is due the mesa-like character of the Cave Hills and Table Mountain. It is characteristically pitted with cavities ranging from half an inch to a foot or more in diameter, which are formed largely by the wind acting on unequally indurated rock. Here and there water and wind have carved large cavities along joint planes. One of these is locally known as Ludlow's cave. Other smaller caves have served as graves for the Indians. On Eagles Nest the sandstone is somewhat cross-bedded and conglomeratic. The pebbles range from 1 inch to 10 inches in diameter, and some of them are slightly angular. Pine trees show a preference for the loose, sandy soil derived from these rocks, and the limits of the sandstone in the Cave Hills are virtually the limits of the forests.

The two distinct cliffs of the North Cave Hills are formed by two phases of sandstone belonging to the Fort Union formation. The lower sandstone, 75 to 100 feet thick, is yellow to brown in color, coarse to fine grained in texture, and massive in appearance and is composed chiefly of subangular quartz grains and accessory mica. It is weakly cemented by lime and in places is notably cross-bedded. Overlying the lower sandstone in the southern portion of the North Cave Hills is about 20 feet of light-colored or whitish argillaceous sandstone, separating it from the succeeding reddish sandstones. In sec. 27, T. 22 N., R. 5 E., a thin bed of lignite occurs in this interval. The upper sandstone is conspicuously cross-bedded, the cross-beds being from 1 to 8 inches thick and in places 30 feet long. The upper sandstone seems to be free from lime, and its coloring is due chiefly

to iron oxide. It is a soft coarse-grained, somewhat massive rock, composed mostly of rounded grains of quartz and small flakes of muscovite. It is about 135 feet thick. A bed of conglomerate, composed of fragments of soft reddish sandstones, occurs near the top. At several places in the Cave Hills the reddish sandstone is succeeded by a bed of quartzite. The following detailed section was measured in sec. 31, T. 22 N., R. 6 E.:

Section of part of the Fort Union formation in the SW. ¼ sec. 31, T. 22 N., R. 6 E.

	Feet.
Sandstone, pitted	5
Sandstone, white, argillaceous, grading into sandstone, white, fine grained, and soft	91
Sandstone	11
Sandstone, yellow, very fine grained, with white sandstone concretions	70
Sandstone, white; rounded fine quartz grains; soft	32
Shale, Ludlow lignitic member of the Lance formation.	
	209

The Fort Union formation in the region about the Lodgepole Buttes and farther east rests on the Cannonball marine member of the Lance formation and consists of less massive beds than in the Cave Hills, being composed of fissile calcareous and arenaceous rocks. The sandstone is made up of fine quartz fragments cemented by calcium carbonate and is light brown, tan, and buff in color. In places it is ripple marked and somewhat cross-bedded. The indurated sandstones and limestones are interbedded with more or less unconsolidated sandy and clayey beds and lignite.

The indurated beds of sandstone and limestone protect the underlying strata from rapid erosion and give rise to the angular shoulder on the outer edge of the plateau, which surrounds the Lodgepole Buttes and extends eastward to the vicinity of Lemmon.

The following are detailed sections of parts of the Fort Union formation south of the Lodgepole Buttes, at Anarchist Butte, and near Lodgepole post office:

Sections of parts of the Fort Union formation.

T. 22 N., R. 12 E., near Lodgepole post office.

	Ft.	in.
Sandstone, loosely cemented	50	0
Shale, bluish gray	10	0
Lignite	1	6
Shale	3	0
Lignite		6
Sandstone, unconsolidated, gray	8	0
Shale	7	0
Lignite	5	0
Sandstone	20	0
Interval to base of Fort Union	120±	
	225±	

Sec. 36, T. 22 N., R. 8 E.

	Ft.	in.
Sandstone, gray to yellow, friable, with indurated concretions	10	0
Shale, grayish, weathers yellow; slightly sandy; thin limonite layers; mica flakes	22	0
Shale, brown		10
Shale, gray to brownish	4	0
Shale, brown	1	0
Shale, grayish; weathers yellow; slightly sandy; thin limonite layers; mica flakes	6	6
Shale, brown to black, carbonaceous	2	0
Shale, grayish, slightly sandy; thin limonite layers; mica flakes	10	9
Shale, brown and gray	3	0
Sandstone, brown, very fine grained, containing clay, with some carbonaceous matter, rather hard		6
Shale, gray to brown	5	6
Shale, brown, very sandy, containing charcoal	2	0
Shale, gray, laminated, sandy, partly carbonaceous	8	0
Shale, brown to dark, fissile	2	4
Shale, gray to yellowish	5	0
Shale, brown to black, fissile	2	0
Shale, gray to yellowish, with thin streaks of limonite; thinly laminated, grading into underlying shale	8	6
Shale, black, brittle, fissile, carbonaceous	1	4
Iron, probably bog iron, containing wood		6
Lignite, dirty		4
Sandstone, brown, bituminous	2+	
Bottom of slope so covered with grass that it is impossible to determine country rock.		
	98	1+

Anarchist Butte, in sec. 34, T. 22 N., R. 9 E.

Sandstone, brown, coarse, forming cap of hill	51	6
Shale, chocolate-colored, with coal smut	1	0
Sandstone, orange to cream-colored, fine grained, with some limonite crusts	20	0
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	0
Shale, chocolate-colored, with some lignite	1	6
Clay, drab	4	0
Quartzite; under surface of layer rather stalactitic	1	6
Clay, lilac-colored	3	0
Shale, black, fissile	1	0
Shale, chocolate-colored, fissile	20	0
Lignite, weathered	1	0
Shale, chocolate-colored	5	0
Lignite, weathered	2	0
Shale, chocolate-colored		6
Sandstone, yellow.		
	130	0

The rocks represented in the interval between the resistant sandstone and limestone of the lower part of the Fort Union and the massive sandstone which caps the Lodgepole Buttes are shaly and carbonaceous, indicating the return to swampy conditions similar to those of the Lance epoch. The beds in this interval are shown in the last two sections given above and are succeeded by a sandstone lens which is represented in the section at Anarchist Butte by the upper four beds. This sandstone is very much like the upper sandstone on the Cave Hills. It is brownish yellow in color and massive in appearance and resists weathering to such an extent as to form an impassable vertical cliff almost continuously around the Lodgpole Buttes. It caps Anarchist Butte and the buttes in Tps. 21 and 22 N., R. 12 E. Its greatest thickness is probably about 100 feet.

A peculiar quartzitic rock occurs at Anarchist Butte and has been traced for many miles in this field as well as in southwestern North Dakota. It is found in place on the top of the Cave Hills, in Lodgepole and Anarchist buttes and several small buttes in T. 22 N., R. 6 E., northwest of Ludlow post office, and in numerous buttes and ridges in Perkins County. The rock on fresh exposure is of a grayish-white to bluish-gray color and is very soft, but on weathering it becomes well indurated and in many places highly polished by wind action. It is composed largely of fine subangular grains of quartz. The rock in places is perforated with impressions of roots and stems, but nothing identifiable was found.

Bowlders of quartzite very similar to those known to be derived from the Fort Union formation and containing impressions of stems and roots are scattered over the surface of much of this field. Two localities are worthy of mention. One is about 2 miles east of Strool, where a ridge about half a mile long and a quarter of a mile wide is formed by angular bowlders as much as 6 feet in diameter, which rest on beds near the middle of the Lance formation. The other locality is south of the Slim Buttes, along Moreau River, where quartzite bowlders as much as 2 feet in diameter cover the surface over an area of several hundred yards and rest on beds very near the base of the Lance formation. The occurrence of angular bowlders 4 to 6 feet in diameter in large numbers and at various altitudes suggest that quartzite probably occurs at other horizons than those in the Fort Union, and, in fact, Todd,[1] in discussing the quartzite, assigns it to the White River formation and gives a section at the south end of the Slim Buttes, including "buhrstone" 1 foot thick, from which, he suggests, the quartzite bowlders may have originated. Darton[2] has noted quartzite, somewhat similar to that described above, in the

[1] Todd, J. E., Geology of South Dakota: South Dakota Geol. Survey Bull. 2, pp. 60–61, 1898.
[2] Darton, N. H., personal communication.

Fox Hills sandstone in Castle Rock, a few miles to the south of this field. It would seem, therefore, that the conditions favorable to the formation of a quartzite existed not only in Fort Union time but also during the earlier epochs and possibly during White River time.

In the part of the Fort Union formation which is exposed in South Dakota there is only one valuable bed of lignite, and that underlies the high ridges north and south of Lodgepole, where it reaches locally a thickness of more than 8 feet. The same bed underlies a number of smaller buttes in adjoining townships, but it is much thinner toward the west.

The line of separation of the Lance from the Fort Union is placed in the eastern part of the field at the top of the beds known to be of marine origin, and in the vicinity of the Cave Hills and Table Mountain at the base of the lowest massive sandstone. It is approximately the line as mapped by Hares [1] during the summers of 1911 and 1912, in Bowman and Billings counties, N. Dak, and by Lloyd in 1912,[2] in Adams and Morton counties, N. Dak.

If there is any unconformity between the Lance and Fort Union in this field it is concealed. Both formations lie so nearly horizontal that it is impossible to detect any difference in the dip and strike.

The only fossils collected from the Fort Union were leaves. These were identified by F. H. Knowlton, as follows:

F 42 (6384). Sec. 34, T. 22 N., R. 9 E., at Anarchist Butte:
- Populus cuneata Newberry.
- Carpites sp.
- Ficus spectabilis? Lesquereux.
- One or two dicotyledons without margin.
- Leguminosites arachioides Lesquereux.
- Sapindus grandifoliolus Ward.
- Populus genatrix? Newberry.

F 49 (6373). SE. ¼ NE. ¼ sec. 4, T. 21 N., R. 12 E.:
- Populus cuneata Newberry.
- Populus amblyrhyncha Ward.
- Platanus sp.
- Ficus? sp.

F 48 (6372). NW. ¼ sec. 3, T. 21 N., R. 12 E.:
- Platanus haydenii Newberry.
- Populus amblyrhyncha Ward.
- Populus cuneata Newberry.

LATER TERTIARY FORMATIONS.

Light-colored clay, marl, sandstone, and conglomerate are exposed in the Slim Buttes, Short Pine Hills, and numerous other isolated hills of northwestern South Dakota. (See Pl. IV.) The lower beds are referred to the White River formation on the basis of the fossils which they contain. The upper beds in the larger areas have been called Arikaree (?) by Darton,[3] and as there is no evidence to the contrary the same nomenclature is used in this report.

[1] Hares, C. J., Lignite in southwestern North Dakota: U. S. Geol. Survey Bull. (in preparation).

[2] Lloyd, E. R., The Cannonball River lignite field, North Dakota: U. S. Geol. Survey Bull. 541, pp. 250–251, pl. 13, 1914.

[3] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, p. 31, 1909.

WHITE RIVER FORMATION (OLIGOCENE).

The cross-bedded White River formation, in some places, appears to be truncated and overlain by a heavy-bedded sandstone. Because of the distinct lithologic character of the beds above and below, the later Tertiary rocks are separated into two formations along this contact, the lower part being referred to the White River formation and the upper part to the Arikaree (?). The White River formation, as thus identified, is about 160 feet thick. It consists of light-colored banded clay and sandstone, white grit, and marl and contains many lenses of concretionary siliceous material. The two sections of the White River formation given below show the character of the formation as exposed in this field.

Sections of White River formation.

Slim Buttes, in sec. 1, T. 17 N., R. 7 E.

	Feet.
Clay, flesh-colored, plastic when wet	12
Sandstone, coarse to extremely coarse, calcareous grit; contains much quartz, many fresh feldspar crystals, some clay pebbles	62
Clay, sandy, banded; contains limonite concretions	66
	140

East Short Pine Hills, in sec. 36, T. 17 N., R. 3 W.

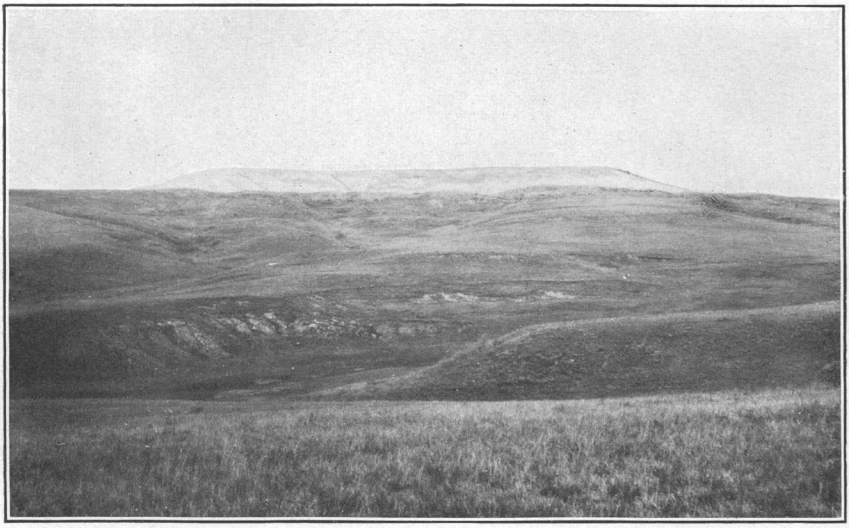
Clay, flesh-colored, calcareous; contains seams of chalcedony as much as three-fourths of an inch thick, and thick plates and irregular masses of siliceous concretions with chalcedony streaks; very plastic	60
Like overlying bed, but does not contain the siliceous plates	30
Sandstone, white, unconsolidated; coarse grit with plastic calcareous clay matrix; weathers into fluted forms	66
Unconformity.	
	156

In sec. 36, T. 17 N., R. 1 E., the White River consists of 60 feet of banded white sandy clay, with small limonite concretions. It has the appearance of worked-over Lance material, with the addition of lighter-colored clay.

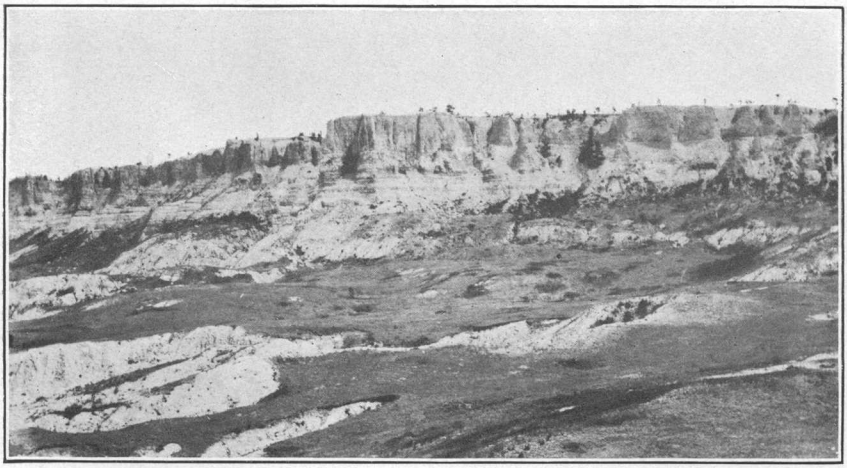
The White River is cross-bedded on a remarkable scale.[1] The cross-bedding, which is exposed in Reva Gap, was considered by Todd[2] to represent structure, which would necessarily involve the underlying formations. However, the outcrop of a bed of lignite in the southwestern part of T. 18 N., R. 8 E., extends almost continuously along parts of three sides of a projecting point in which the White River formation exhibits an apparent dip of nearly 30°. This lignite bed, which occurs only a few feet below the base of the White River formation, does not dip in accordance with the apparent structure of the White River, but its attitude corresponds with that of the almost flat-lying Ludlow lignitic member of the Lance formation,

[1] Winchester, D. E., Cross-bedding in the White River formation of northwestern South Dakota: Jour. Geology, vol. 21, No. 6, pp. 550–556, 1913.

[2] Todd, J. E., Recent geological work in South Dakota: Am. Geologist, vol. 16, p. 303, 1895.



A. ONE OF THE SMALL BUTTES NORTHEAST OF BISON, S. DAK., SHOWING WHITE RIVER FORMATION RESTING ON LANCE FORMATION.



B. SOUTH FACE OF SLIM BUTTES, SHOWING CLIFF FORMED BY ARIKAREE (?) SANDSTONE.

below. Other good examples of this large scale cross-bedding appear in the Slim Buttes, in sec. 17, T. 18 N., R. 8 E., and in Flat Top Butte, in sec. 30, T. 17 N., R. 9 E. At none of these places does the attitude of the underlying Ludlow lignitic member correspond with the apparent structure exhibited in the White River formation, and therefore the angles exhibited in the White River are interpreted as being due entirely to cross-bedding.

The White River formation lies unconformably on the lower part of the Lance in the Short Pine Hills, on the Ludlow lignitic member in the Slim Buttes, and on the Fort Union in White Butte, T. 22 N., R. 14 E., and in the Cave Hills. The amount of erosion represented by this unconformity is at least 750 feet.

The following fossils were collected from the formation and identified by C. W. Gilmore and J. W. Gidley as White River forms.

F 26. SE. ¼ NE. ¼ sec. 11, T. 16 N., R. 8 E. (from yellow and pink clay near base of White River formation).
Distal end of humerus, probably Merycoidodon culbertsonii.
Fragment of turtle, probably Stylemys nebrascensis.

F 39. Sec. 30, T. 17 N., R. 9 E. (from cross-bedded clay and sandstone at northwest corner of Flat Top Butte).
Merycoidodon culbertsonii Leidy, skull with lower jaws, fragments of lower jaw, limb bones, and foot bones.
Mesohippus? bairdi Leidy, pieces of lower jaws.
Septomeryx? evansi Leidy, skull without teeth and fragments of lower jaw with last lower molar.
Hyracodon nebrascensis Leidy, upper premolar and incisor.

F 27. NE. ¼ SW. ¼ sec. 32, T. 18 N., R. 8 E. (from cross-bedded sandy clay near the base of the White River formation).
Hyracodon nebrascensis Leidy, upper and lower jaws of right side, containing most of molar-premolar series.

F 52. Sec. 3, T. 18 N., R. 14 E. (from clay bed at top of small butte).
Probably Cænopus or Aceratherium, fragments of pelvis.

F 29. Sec. 17, T. 18 N., R. 8 E. (from cross-bedded clay and sandstone near the base of the White River formation).
Various fragments determinable as Merycoidodon culbertsonii Leidy and Hyracodon sp.
Merycoidodon culbertsonii, fragments of skull and teeth.
Hyracodon astragalus.
Septomeryx evansi?
Palæolagus sp.
Mesohippus sp.

F. 21. NW. ¼ SW. ¼ sec. 25, T. 19 N., R. 7 E.
Titanotherium.
Cænopus.
Aspideretes.

F 3. SE. ¼ SW. ¼ sec. 36, T. 17 N., R. 1 E.
Merycoidodon.

F 4. SE. ¼ NW. ¼ sec. 17, T. 17 N., R. 2 E.
Cænopus n. sp.
Hoplophoneus?
Septomeryx.
Elotherium mortoni?

Several specimens of a shell reported by William H. Dall to be "probably an undescribed species of Polygyra, allied to the recent Albolabris and having an Eocene aspect," were found in the same beds from which collection F 39 was taken.

ARIKAREE (?) SANDSTONE (MIOCENE?)

The formation here referred to, the Arikaree (?), was called Loup Fork by Todd [1] and Arikaree (?) by Darton.[2] These authors found no fossils in the beds, and consequently based their correlations purely on lithologic grounds.

The formation is composed almost wholly of sandy tuffaceous beds, some of which on weathering show peculiar concretionary forms. Lithologically they resemble the Arikaree in southern South Dakota, which was described and pictured by Darton.[3] The formation in different parts of the Slim Buttes ranges in thickness from 75 to 225 feet. At the base is a greenish-gray, heavily bedded, almost massive sandstone, very fine grained and calcareous. Thin lenses of conglomerate also occur at or near the bottom. The rocks of the formation contain quartz, feldspar, augite, hornblende, epidote, biotite, calcite, and fragments of volcanic glass most of which are angular to subangular. Volcanic material in considerable abundance is revealed in all the slides prepared from these rocks. The Arikaree (?) is the cliff-making formation of the Slim Buttes (see Pl. IV, *B*, p. 32) and of the East and West Short Pine Hills. The following stratigraphic sections show its general character:

Sections of Arikaree (?) sandstone.

Sec. 1, T. 17 N., R. 7 E.

	Ft.	in.
1. Sandstone, greenish gray, rather thin bedded, fine grained, calcareous, and clayey; some thin layers, hard and brittle, show cross-bedding on small scale	68	0
2. Sandstone, similar to No. 1, but more massive and with less clay; some zones composed wholly of concretions, with concentric structure and translucent interior; some of the concretions stalactitic; the surface of this sandstone weathers rough like a complicated carving; it is cross-bedded on a large scale, but not so much so as parts of the White River formation	114	0
3. Conglomerate, pebbles like No. 2, as much as 4 inches in size; the matrix contains waterworn fragments of bones; maximum thickness, 15 feet	7	6
4. Sandstone, thin bedded, much like No. 2	9	0
5. Sandstone and clay, interbedded; surfaces of beds show mud cracks	6	0
Unconformity (?).		
	204	6

[1] Todd, J. E., Recent geological work in South Dakota: Am. Geologist, vol. 16, p. 202, 1895.

[2] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, p. 31, 1909.

[3] Darton, N. H., Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 4, pp. 743–747, 1898.

Sec. 36, T. 17 N., R. 3 E.

	Ft.	in.
Top of East Short Pine Hills.		
Sandstone, quartzitic, containing chloritic material; resists erosion to a marked degree; ranges in thickness from 2 to 5 feet..	3	6
Sandstone, fine grained, greenish white, calcareous; forms a steep cliff; weathered surface shows concretionary structure; typical specimens contain angular feldspar, biotite, quartz, epidote, calcite, and fragments of glass, together with chloritic material; called a rhyolite tuff by E. S. Larsen, of the U. S. Geological Survey.....	140	0
Unconformity (?).		
	143	6

Sec. 36, T. 17 N., R. 1 E.

Top of mesa.		
Sandstone, hard, green, with small veins of chalcedony.....	13	0
Sandstone, homogeneous, fairly soft, fine grained, with lavender tinge; conchoidal fracture; some parts rather thin bedded and some massive; some zones minutely cross-bedded; bedding surfaces show mud cracks and ripple marks.....	130	0
Unconformity (?).		
	143	0

No attempt was made in the field to map the White River and Arikaree (?) formations as separate units, although the hachures on Plate I, which represent the cliff faces about the Slim Buttes, West Short Pine Hills, and adjacent buttes closely approximate the limit of the Arikaree (?) sandstone. Where no hachures are shown that formation is absent.

The only fossils found in the Arikaree (?) sandstone were waterworn fragments of bone from a conglomerate near the base of the formation. The specimens were identified by Gidley as follows:

F 25. Sec. 8, T. 16 N., R. 8 E. (from conglomerate near base of Slim Buttes).
Stylemys nebrascensis Leidy.
Hyænodon cruciens Leidy.
Oreodon sp.
Agriochœrus sp.
Age, lower Oligocene, probably equivalent to Titanotherium zone.

F 2. Sec. 36, T. 17 N., R. 1 E.

F 17. SW. ¼ sec. 26, T. 17 N., R. 7 E. (from bed near the base of the formation; the specimens so much waterworn that the bones may have been derived from the underlying White River formation).
Fragments of Merycoidodon.

These collections indicate that the rocks containing them were derived from the White River formation.

QUATERNARY SYSTEM.

The materials of Quaternary age in northwestern South Dakota include terrace deposits along all the principal streams, the deposits on the recent flood plains of the streams, and sand dunes covering

large areas along the South Fork of Grand River in Harding County. No study was made of these deposits and no attempt was made to map them.

STRUCTURE.

The lignite-bearing formations of South Dakota occupy a very shallow structural basin (fig. 3), the main axis of which trends approximately north and lies well toward the eastern edge of the field. The contours in figure 3 show that the beds at the top of the lower part of the Lance formation descend from an altitude of 3,300 feet in T. 22 N., R. 3 E., and 2,700 feet in T. 16 N., R. 15 E., to 2,150 feet in the vicinity of Lemmon. The converging dips indicate that this area lies on the rim of a structural basin the center of which is in North Dakota somewhere north of Lemmon. There are several irregularities in the general structure. Along the western margin of the basin the rocks are most steeply inclined and their dip varies considerably in different areas, but in the central part of the basin they are almost horizontal. South of Grand River, in T. 19 N., R. 8 E., the dip is about 65 feet to the mile (less than 1°) toward the east; at the south end of the Slim Buttes it is approximately 25 feet to the mile toward the north and the strike is about N. 80° W. In the southeastern part of the field, near Chance, the dip is about 12 feet to the mile N. 10° E., whereas at Meadow it is 15 feet to the mile N. 10° W., and at Breckenridge only 7 feet to the mile N. 60° E.

West of the Cave Hills and Slim Buttes the lower strata are brought up in a series of low anticlines. The southern extension of the Glendive anticline of Montana as described by Calvert[1] exposes the top of the Fox Hills sandstone east of Little Missouri River near the North Dakota line and is represented to the southeast by gentle anticlinal structure in the Lance formation. A second fold nearly parallel to the Glendive anticline results in the exposure of the Pierre shale in a small area south of the West Short Pine Hills. The general direction of the two folds is markedly parallel to that of the Black Hills uplift, to the south, and it is probable that they as well as other folds in eastern Montana were produced at the same time and by the same forces.

Very little true faulting has occurred in the field—in fact, the only faults observed are one in the Phillips lignite mine, where the bed is displaced about 3 feet, and several very small ones in the Slim Buttes. There are, however, numerous places where slumping of beds produces effects similar to faulting as well as folding. This slumping is not confined to any particular formation, as rocks of the Lance and the younger formations are much distorted and broken by landslides. The largest landslide in the field (see Pl. III, *B*, p. 10) is in

[1] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, p. 201, 1912. (Calvert calls this the Cedar Creek anticline.)

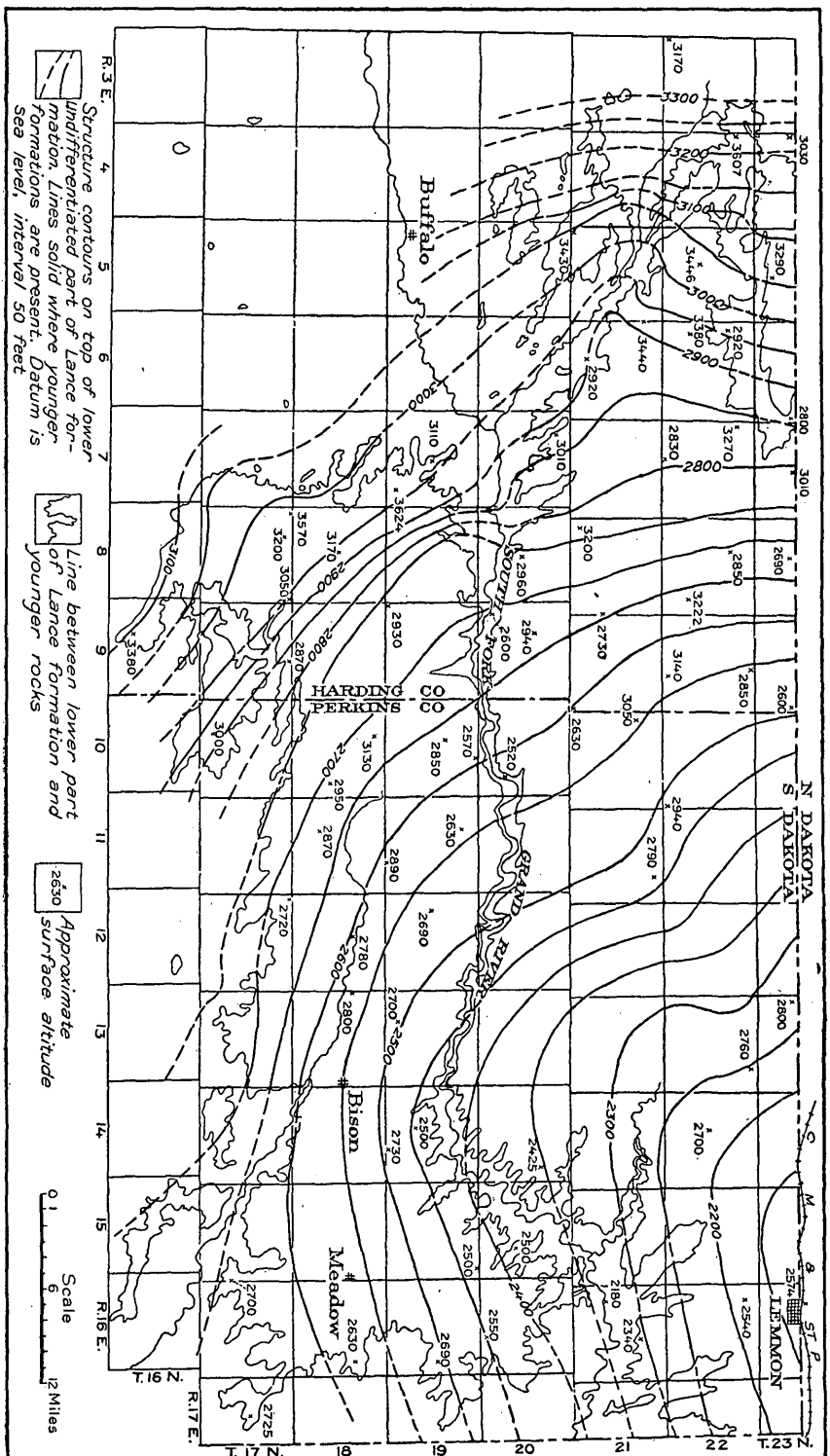


FIGURE 3.—Map showing geologic structure of the lignite field of northwestern South Dakota.

sec. 20, T. 19 N., R. 8 E., where a block of the White River formation about 125 feet thick, 500 feet wide, and half a mile long is exposed in the bottom of a narrow valley. The base of the formation, which is broken and tilted in this slide, is nearly 200 feet lower in altitude than the corresponding horizon in the Slim Buttes, three-fourths of a mile away, and much lower than rocks of the Lance formation which crop out along the sides of the valley. In sec. 27 of the same township an area of Lance rocks, 600 by 2,000 feet, containing a thick bed of lignite, is included in a landslide.

LIGNITE.

LOCATION AND EXTENT.

The lignite field of South Dakota forms the southeastern part of the great lignite field which lies mainly in Montana and North Dakota. From the time of the first exploration of Missouri River by Lewis and Clark in 1804–5 it has been known that thick beds of lignite occur at many places in North Dakota, but their extent has never been accurately determined. The delimitation of the field is complicated by the fact that the thickest and most persistent beds of lignite are contained in the Fort Union formation, and that generally thinner beds occur in the underlying Lance. The extent of the Fort Union in South Dakota was not known prior to the field work on which this report is based, and many writers have assumed that it is present in much of the area supposed to be lignite bearing. The work of 1911 and 1912, however, has shown that the Fort Union formation extends only a short distance into South Dakota and that in the remainder of the field here discussed the lignite beds present are those of the Lance formation. In general the thickness of individual beds, as well as the number of beds, in the Lance decreases toward the southeast, so that although several comparatively thick beds occur in northeastern Harding County, there is but little lignite of commercial value in southeastern Perkins County.

The lignite beds in the lower part of the Lance, although present in a great number of places, are generally thin and of local extent. Most of these lenses are found in the upper 100 feet and almost none of them in the lower 200 feet. One bed in T. 21 N., R. 5 E., and one in T. 21 N., R. 2 E., are thick enough to be of local value.

Lignite has been found in all parts of the field at or near the base of the Ludlow lignitic member of the Lance. The most valuable beds in the field are in this member in the eastern and northeastern parts of Harding County and the western part of Perkins County south of the South Fork of Grand River. The beds in the lower 150 feet of the Ludlow member are in general thin and nonpersistent except around the borders of the Slim Buttes. In the upper 200 feet there are two or three persistent beds, which are most important in

the North and South Cave Hills and Table Mountain and in eastern Harding County north of the South Fork of Grand River and Bull Creek. Lignite beds in this part of the Lance are also well developed in T. 19 N., Rs. 10 and 11 E. These beds, however, are lenticular and the thicknesses are maintained for only short distances. The Cannonball marine member of the Lance was laid down in salt water and does not contain any lignite

The lower part of the Fort Union formation contains practically no lignite in this field, but a thick bed is exposed about 100 feet above the base of the formation. This bed underlies a group of hills north and south of Lodgepole, in Tps. 21 and 22 N., R. 12 E., where it reaches a maximum thickness of 8 feet 10 inches. A few other high buttes in adjoining townships are underlain by the same bed, but it is much thinner both to the west and north.

The rocks overlying the lignite are in many places baked and even fused, the amount of alteration being controlled partly by the quality and thickness of the lignite bed but more by the conditions of burning.

PHYSICAL CHARACTER.

No distinction in character has been observed in this field between the lignite of the Lance and that of the Fort Union formation. Most of the lignite is very dark brown, almost black in color, but the powder is brown. Most of the fresh material has a dull luster and much of it a tough woody texture. Detailed examination of the more woody parts shows some variation in texture, color, and luster. Small lenses of shiny black lignite, ranging in thickness from a thin film to an inch or more, alternate with dark-brown lignite which has not nearly so bright a luster. Both varieties retain in places the fibrous character of the wood from which they were derived. These characteristics are well shown in the lignite from Jones's mine, in sec. 35, T. 19 N., R. 10 E. At Phillips's mine, in sec. 7, T. 17 N., R. 11 E., on a bed near the top of the lower part of the Lance, the lignite is predominantly of the hard black variety and has well-developed cleavage, resembling very closely the subbituminous coal of eastern Wyoming. The analyses of fresh samples from these two mines, however (see table, pp. 42–43), show no appreciable difference in chemical composition. As a rule the lignite in which the woody texture is not well preserved has a dull luster and contains a comparatively high percentage of ash.

On exposure to the air the lignite of this field loses a considerable part of its moisture, shrinks, and soon falls to pieces, a characteristic which makes the shipping of it in open cars to distant markets almost impossible and will prove a serious handicap in its exploitation. The breaking up or checking begins almost immediately when fresh lignite is exposed to the air. The cracks on the surface are in some

places approximately at right angles, so that the small blocks which scale off are roughly cubical in form. In other places the checking is more irregular. In the best lignite the weathered surfaces are black and have a bright vitreous luster, even though in the unweathered condition the lignite is brown and has a dull luster. As the percentage of ash increases, the luster of the weathered surface is duller. The weathering of lignite of different grades is so characteristic that an examination of the weathered face of an exposed section will, in many cases, afford a better conception of the character of the lignite than an examination of the fresh lignite.

CHEMICAL COMPOSITION.

For the sake of uniformity in the comparison of coal and lignite, it is necessary that samples for chemical analysis be free from weathering, but in a region where the greater part of the lignite is taken from strip pits it is difficult to procure fresh material. Eight samples obtained in the northwestern South Dakota field were analyzed at the Pittsburgh laboratory of the Bureau of Mines. Five of these samples were obtained from drift mines and the other three from strip pits. The samples were collected in accordance with the regulations of the United States Geological Survey, which in brief are as follows: From a clean, fresh face a channel is cut perpendicularly from roof to floor, the partings that are thrown out in mining being discarded. The material thus obtained is broken to pass through a ½-inch screen and the sample is reduced by quartering to about 1 quart, which is placed in a galvanized-iron can, sealed, and sent immediately to the laboratory. With the analyses from northwestern South Dakota are included for the sake of comparison analyses of fresh lignite from four producing mines in widely separated parts of North Dakota.

In the following table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form of analysis is not well suited for comparison of one coal or lignite with another, because the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of different samples of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to the general purposes of comparisons. Analysis C represents the theoretical condition of the lignite after all the moisture has been eliminated. Analysis D represents the lignite after all moisture and ash have been theoretically removed. This is supposed to represent the true lignitic substance, free from the most significant impurities. Forms C and D are obtained from the others by recalculation.

In the analytical work chemists recognize that it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only. In the ultimate analyses the ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. As calorific determinations to individual units are not reliable, in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens, the value of a British thermal unit being about one-half that of a calorie.

Analyses of lignite samples from the northwestern South Dakota and adjoining lignite fields.

[Made by the Geological Survey and the Bureau of Mines, E. E. Somermeier and A. C. Fieldner, chemists in charge.]

Name of mine and location.	Location.				No. on Plate I or II.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.			Ultimate.						Heating value.	
	Quarter.	Section.	Township.	Range.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Phillips mine	SW...	7	17 N.	11 E.	879	12488	30.1	A	42.5	a 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	5.33	50.39	.88	28.86	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
Knudsen mine	NE...	2	17 N.	10 E.	811	12154	19.6	A	34.7	a 26.4	27.6	11.3	1.08	.....	.....	.....	.....	.....	.....
								B	18.8	32.9	34.4	13.9	1.34	.....	.....	.....	.....	.....	.....
								C	.....	40.5	42.3	17.2	1.65	.....	.....	.....	.....	.....	.....
								D	.....	48.8	51.2	.....	1.99	.....	.....	.....	.....	.....	.....
Jones mine	NW...	35	19 N.	10 E.	824	12453	26.0	A	39.2	a 24.7	27.8	8.35	2.22	6.60	38.02	.53	44.28	3,505	6,310
								B	17.8	33.3	37.6	11.28	3.00	5.02	51.38	.71	28.61	4,735	8,520
								C	.....	40.6	45.7	13.72	3.65	3.70	62.49	.87	15.57	5,760	10,370
								D	.....	47.2	52.8	.....	4.23	4.29	72.43	1.01	18.04	6,675	12,020
Mine of Henry Hilton		6	20 N.	5 E.	144	13221	33.0	A	39.8	a 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
M. M. Mendenhall, prospect.	.....	1	17 N.	7 E.	325	13220	34.7	A	41.5	a 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
Do	.....	1	17 N.	7 E.	326	13222	34.3	A	41.1	a 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
Newcomb mine	SW...	10	20 N.	9 E.	762	15062	26.6	A	34.7	a 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

Nelson mine	NW	29	21 N.	12 E.	937	14354	21.2	A	33.3	[a] 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
								C		43.4	40.9	15.7	1.14					5,795	10,430
								D		51.5	48.5		1.35					6,875	12,380
Nipper & Monroe mine, 3½ miles northeast of Haynes, N. Dak.	NW	16	129 N.	94 W.		14542	14.5	A	32.6	[a] 30.6	28.5	8.3	1.53					4,085	7,360
								B	21.2	35.8	33.3	9.7	1.79					4,780	8,600
								C		45.4	42.3	12.3	2.27					6,070	10,920
								D		51.8	48.2		2.59					6,920	12,460
Mine of Washburn Lignite Coal Co., Wilton, N. Dak.		1	142 N.	80 W.		1935	32.3	A	40.5	27.1	27.4	5.0	.76					3,690	6,640
								B	12.2	39.9	40.4	7.5	1.12					5,450	9,810
								C		45.5	46.0	8.5	1.28					6,205	11,170
								D		49.7	50.3		1.40					6,785	12,210
Mine of Consolidated Coal Co., Lehigh, N. Dak.		8	139 N.	95 W.		1971	35.6	A	42.1	24.5	25.7	7.7	1.13					3,420	6,160
								B	10.0	38.1	40.0	11.9	1.75					5,310	9,560
								C		42.4	44.4	13.2	1.95					5,905	10,630
								D		48.8	51.2		2.25					6,805	12,250
Mine of U. S. Reclamation Service, 3 miles northeast of Williston, N. Dak.		7	154 N.	100 W.		12533	33.2	A	43.9	[a] 24.9	25.4	5.8	.49					3,300	5,940
								B	16.0	37.2	38.1	8.7	.73					4,940	8,890
								C		44.3	45.3	10.4	.87					5,875	10,580
								D		49.5	50.5		.97					6,555	11,800
Scranton mine of Chas Liddell, Scranton, N. Dak.	SW	24	131 N.	100 W.		14485	22.5	A	34.8	[a] 31.1	26.0	8.1	.66					3,840	6,920
								B	15.9	40.1	33.5	10.5	.85					4,960	8,920
								C		47.7	39.8	12.5	1.01					5,890	10,610
								D		54.5	45.5		1.15					6,730	12,120

[a] Volatile matter determined by modified method.

Laboratory No. 12488. Sample of lignite bed near top of lower part of Lance formation, in Phillips mine, in sec. 7, T. 17 N., R. 11 E., 5 miles south of Strool, S. Dak.; collected by Dean E. Winchester, July 26, 1911, from fresh face of lignite at end of main entry 150 feet from mine mouth. At the point of sampling the bed is 2 feet 5 inches thick (see No. 879, Pl. XI), all of which was represented in the sample. The sample was unweathered and somewhat wet.

Laboratory No. 12454. Sample of lignite bed at base of Ludlow lignitic member of the Lance formation, from Knudsen mine (see Pl. V, *A*), in sec. 2, T. 17 N., R. 10 E., 5 miles southwest of Strool; collected by Dean E. Winchester, July 21, 1911, from fresh face of coal about 150 feet from mine mouth. The section of the lignite bed at the mine mouth is shown graphically on Plate XI, No. 811. The upper 2 feet 7 inches of lignite was included in the sample. The mine was dry and the lignite unweathered.

Laboratory No. 12453. Sample from a lignite bed in the upper part of the Ludlow lignitic member of the Lance formation, from the Jones mine (see Pl. V, *B*), in sec. 35, T. 19 N., R. 10 E., 6 miles northwest of Strool, S. Dak.; collected by Dean E. Winchester, July 22, 1911, from a fresh face of lignite at the end of the main entry 100 feet from the mine mouth and under about 75 feet of cover. The section at this point is shown on Plate XI, No. 824. The mine was being worked at the time of examination so that the sample for analysis was free from weathering.

Laboratory No. 13221. Sample from a lignite bed near the top of the Ludlow lignitic member of the Lance formation, from the Hilton mine, in sec. 6, T. 20 N., R. 5 E., 11 miles north of Buffalo, S. Dak.; collected by E. M. Parks, October 4, 1911, from fresh face of lignite at end of main entry, 100 feet from mine mouth. Although the bed contains a total of 11 feet 1 inch of lignite only 7 feet 2 inches is mined. A detailed section of the lignite bed at the Hilton mine is shown on Plate VII, No. 144. At the time of sampling the mine had been in operation for about a year.

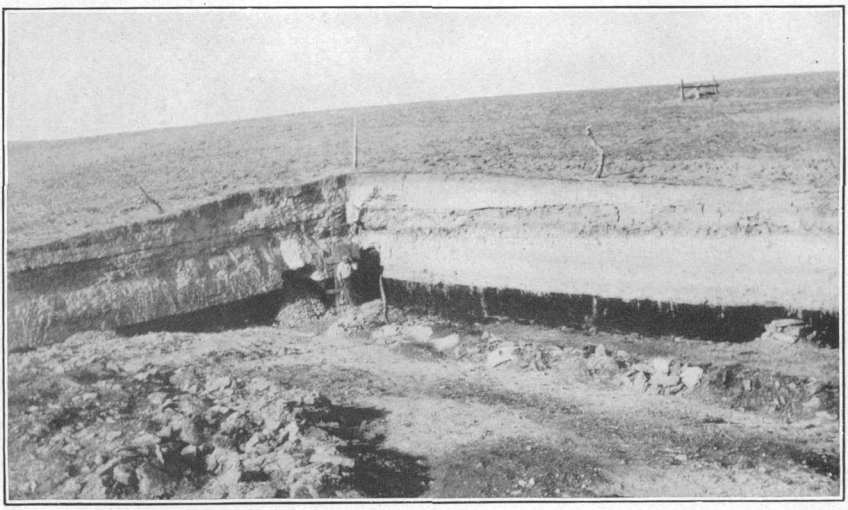
Laboratory Nos. 13220 and 13222. Samples from lignite beds in Ludlow lignitic member of Lance formation, from the Mendenhall strip pit, in sec. 1, T. 17 N., R. 7 E., S. Dak.; collected by E. M. Parks, August 17, 1911, from faces of beds in an old strip pit after digging back 2 feet in order to get as fresh a sample as possible. Sample No. 13220 represents the lignite of the lower bed; No. 13222 represents that of the upper bed. (See Pl. VII, Nos. 325 and 326.)

Laboratory No. 15062. Sample from Newcomb lignite bed, in the Ludlow lignitic member of the Lance formation, from the Newcomb mine (strip pit), in sec. 10, T. 20 N., R. 9 E., about 28 miles south of Reeder, N. Dak.; collected by J. B. Reeside, jr., October 19, 1912, from face of bed in an open pit; somewhat weathered. A section of the bed at the Newcomb mine is shown graphically on Plate IX, No. 762.

Laboratory No. 14354. Sample from lignite bed in Fort Union formation, from the Nelson mine, in sec. 21, T. 29 N., R. 12 E., 3 miles south of Lodgepole, S. Dak.; collected by E. Russell Lloyd, July 3, 1912, from fresh face of lignite 140 feet from mine mouth, under about 35 feet of cover. The full thickness of the bed was not exposed at this place. The thickness of the part that is being mined is 7 feet (see Pl. X, No. 937), all of which is represented in the sample. Both the roof and floor of the mine at the point of sampling were lignite.

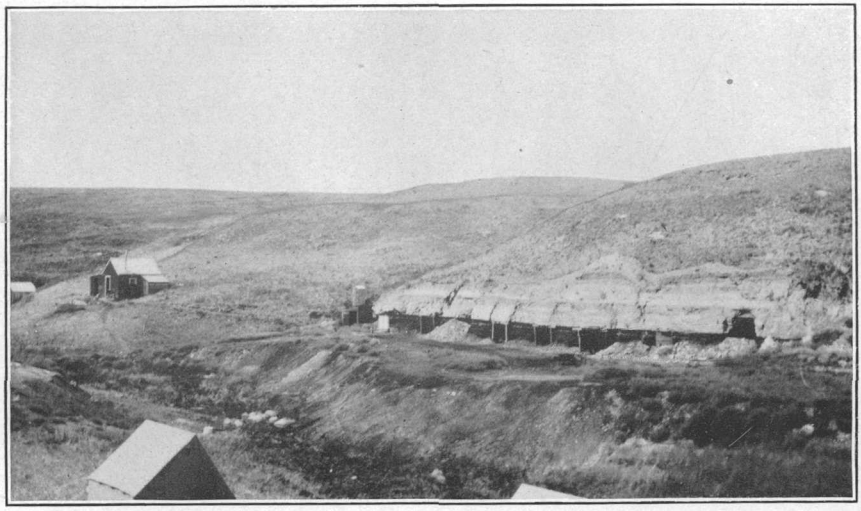
Laboratory No. 14542. Sample from the Haynes lignite bed, in the Fort Union formation, in the Nipper & Monroe mine, 3½ miles northeast of Haynes, N. Dak.; collected by E. Russell Lloyd, July 30, 1912, in entry about 630 feet nearly due east from the mine mouth. The thickness of the bed at this point is about 12 feet, of which the lower 8 feet 3 inches is being mined and was sampled.

Laboratory No. 1935. Sample from a lignite bed in the Fort Union formation, from mine of Washburn Lignite Coal Co., Wilton, McLean County, N. Dak.; collected by M. R. Campbell, August 3, 1905, at 1,750 feet from shaft. The thickness of the bed at this point is 9 feet 6 inches, of which the lower 6 feet 6 inches was sampled.



A. KNUDSEN MINE.

Showing the general character of the strip-pit mines of the region.



B. JONES LIGNITE MINE, NORTH OF STROOL, S. DAK.

Laboratory No. 1971. Sample from a lignite bed in the Fort Union formation, in mine of the Consolidated Coal Co., at Lehigh, Stark County, N. Dak.; collected by M. R. Campbell, August 5, 1905, at 1,900 feet from mine mouth. The thickness of the bed at this point is 6 feet 4 inches, of which the lower 5 feet was sampled.

Laboratory No. 12533. Sample from a lignite bed in the Fort Union formation, from mine of U. S. Reclamation Service 3 miles northeast of Williston, Williams County, N. Dak.; collected by Frank A. Herald, August 16, 1911, at 1,225 feet east from mine mouth. The thickness of the bed at this point is 10 feet 3 inches, of which the lower 8 feet was sampled.

Laboratory No. 14485. Sample from Harmon (?) lignite bed, in the Fort Union formation, from the Scranton mine of Charles Liddell, Scranton, Bowman County, N. Dak.; collected by C. J. Hares, June 30, 1912, from face of east entry, 1,000 feet from mine mouth. The total thickness of the bed is 20 feet 3½ inches. The sample represents 6 feet near the middle of the bed.

In a general way the comparative values of the lignite from different mines and different beds can be obtained from the heating values of the air-dried samples (form B of analysis). This criterion, however, must be modified for lignite in which the loss of moisture on air-drying is comparatively small, as in some of the samples of North Dakota lignite. In the lignite from South Dakota whose analyses are presented above the air-drying loss is fairly uniform. The heating values show that they compare very favorably with lignite that is being mined on a large scale in North Dakota.

All fresh lignite contains a high percentage of moisture, a large part of which is set free on exposure to the air, and a resultant shrinkage takes place, causing the lignite to check or break up into small pieces. There is also a large amount of pyrite or marcasite distributed both along joint planes in large lenses and balls and disseminated in small particles throughout the bed. The larger lenses and balls are thrown out in sampling, so that the sulphur in the bed is greater than is shown by the analysis.

A large part of the northwestern South Dakota lignite field is at present far from a railroad, and therefore the settlers in the region furnish the only market for the lignite. Several small mines have been opened and operated to supply this local trade. Drift mines have been opened in the vicinity of Lodgepole, Strool, and the South Cave Hills.

In nearly all parts of the field the lignite is obtained for local use by stripping off the surface material near the outcrop, and although the labor involved in this process is comparatively great, it seems to be at present the most economical method of mining, for the shale or clay which in most places overlies the lignite is generally not sufficiently compact to serve as a roof.

The lignite is used generally for domestic purposes, but there is a growing demand for it as fuel for the steam plow outfits which are being operated in this part of South Dakota. The low grade and extremely poor stocking qualities of the fuel render it unfit for

shipping in open cars, so that the development, for some years at least, will be limited by the local demand. Experiments made by the Bureau of Mines at Pittsburgh [1] and by the experiment station of the North Dakota School of Mines [2] have proved that the Dakota lignites can be made into briquets at a cost which would place them on the market in favorable competition with high-grade coals. Good producer gas can also be manufactured from lignite, and this may furnish an important market use for the lignite of this field.

AVAILABLE LIGNITE.

In computing the probable amount of lignite available in northwestern South Dakota, only those areas are considered which are known to be underlain by lignite of sufficient thickness to be classified as coal land by the Geological Survey. The lignite of this field has a heating value on air-dry analysis of 8,090 to 8,830 British thermal units,[3] as shown by the chemical analyses (pp. 42–43), and, according to the regulations of the Department of the Interior, a bed of lignite with this heating value must be 2 feet 10 inches thick in order to be considered sufficiently valuable for classification as coal land.

In calculating the tonnage of any lens of lignite its area is determined and the average of the several measurements along the outcrop is assumed to represent the average thickness of the bed. The total content of the lens is determined by multiplying the area in square miles by the average thickness in feet, and this by 1,152,000, the number of short tons of lignite in a square mile of land underlain by a bed 1 foot thick and having a specific gravity of 1.3. By this method it is estimated that there is in Perkins and Harding counties minable lignite amounting to about 1,096,480,000 tons.

DETAILED DESCRIPTIONS BY TOWNSHIPS.

T. 16 N., R. 1 E.

The surface of the northwestern part of T. 16 N., R. 1 E., is a rolling prairie, which slopes gradually upward to the southeast and culminates in a low divide surmounted by a few bare "mud" buttes. The lower part of the Lance formation outcrops throughout most of the township, but the underlying Fox Hills sandstone and Pierre shale are the surface rocks in a small area in the southeast corner. The Fox Hills could not be mapped accurately on account of lack of exposures, but it occupies a narrow belt surrounding the Pierre shale. The strata dip gently to the west. No bed of lignite is exposed in this township.

---

[1] Wright, C. L., Briquetting tests of lignite at Pittsburgh, Pa., 1908–9: Bureau of Mines Bull. 14, 1911.

[2] Babcock, E. J., Investigations of lignite coal relative to the production of gas and briquets, North Dakota Univ., Grand Forks, N. Dak.

[3] A British thermal unit is the quantity of heat required to raise the temperature of 1 pound of water 1° F., the water being at the temperature of maximum density, 39.1° F.

T. 17 N., R. 1 E.

The western part of T. 17 N., R. 1 E., lies in the low flat valley of Little Missouri River, which flows across the northwest corner. Along the east border is the West Short Pine Hills mesa, which rises abruptly to an elevation of nearly 400 feet above the surrounding country. At the foot of the mesa cliffs is a narrow, deeply dissected area occupied by rocks slumped and washed down from the sides of the mesa. The entire area between the mesa and the river valley is rugged and cut by small streams.

The Lance formation outcrops at the surface throughout the township, except in the West Short Pine Hills, where the White River formation rests unconformably upon the Lance and is in turn overlain by a thick sandstone cap or rim rock that is assigned to the Arikaree (?) sandstone. The strata dip slightly to the west in the central part of the township. In the eastern part there is little opportunity to observe the structure of the Lance formation because of the cover of younger rocks. A general study of the region shows that the axis of a low anticline passes through the township in a nearly north-south direction. No lignite is exposed in the township.

T. 18 N., R. 1 E.

With the exception of a small area of rolling land in the southeastern part, T. 18 N., R. 1 E., lies entirely in the level valley of Little Missouri River, which flows northeastward across the township. This stream, even in the driest years, contains running water, but during the summer months its flow is insufficient to provide much water for irrigation. Camp Crook, in secs. 2 and 3, is the most important town in this part of the field. It has mail and stage connections with Belle Fourche, 70 miles to the south, on the Chicago & Northwestern Railway, and with Bowman, N. Dak., 60 miles to the northeast, on the Chicago, Milwaukee & St. Paul Railway.

The surface rocks belong to the lower part of the Lance formation. The top of the Pierre shale is less than 100 feet below the surface at Camp Crook, as determined by a well. Good rock exposures are rare because of the grass-covered surface. The rock structure is wholly obscured, but a gentle northward-trending anticline is supposed to pass through the township, its axis being near Camp Crook. No bed of lignite is known to outcrop in the township.

T. 19 N., R. 1 E.

The surface in the eastern three-fourths of T. 19 N., R. 1 E., is low and flat, but along the Montana line there is a series of rocky hills covered by a sparse pine growth. The surface rock is somber-colored shale belonging to the lower part of the Lance formation, except that the rocky hills in the western part of the township are

capped by a massive sandstone bed of the Ludlow lignitic member of the Lance. This sandstone shows a distinct westerly dip that increases in amount toward the north until at location 4,[1] in sec. 5, it is more than 10°. The structure is obscured elsewhere in the township, but from data collected in adjacent areas it is inferred that the axis of a gentle north-south anticline passes through the central part of the township.

Two lignite beds 50 to 75 feet apart outcrop in the western part of the township. The lower bed, which occurs at the base of the Ludlow lignitic member of the Lance, has a maximum thickness of 2 feet 7 inches at location 3 in the NE. ¼ sec. 8. The following sections show its character at the exposures in this township:

Sections of lignite beds measured in T. 19 N., R. 1 E.

Location 1. SE. ¼ sec. 30.

	Ft.	in.
Clay.		
Shale, lignitic, and lignite	1	0
Shale, brown		8
Lignite, dirty		7
Shale, brown		8
Lignite, dirty		10
Total section	3	9
Total lignite	1	5

Location 2. NE. ¼ sec. 30.

	Ft.	in.
Shale, brown	2	0
Shale, carbonaceous	1	6
Shale, brown	1	8
Lignite	1	7
Shale.		
Total section	6	9
Total lignite	1	7

Location 3. NE. ¼ sec. 8.

	Ft.	in.
Lignite, good at bottom and dirty at top	2	7

Location 4. NE. ¼ sec. 5.

	Ft.	in.
Shale.		
Lignite	2	0
Shale.		

The upper bed is represented in this township by 5 feet of interbedded shale and dirty lignite at a single exposure near the center of sec. 8. Elsewhere its outcrop is marked by clinker, except in the ridge in sec. 20, where it is concealed by débris from the overlying beds. Farther west, in Montana, several strip pits have been opened on this bed, and lignite has been mined to supply the local demand in Camp Crook and vicinity.

T. 20 N., R. 1 E.

The surface of the eastern two-thirds of T. 20 N., R. 1 E., is low and flat and is crossed by sluggish streams which are fed by springs from the hills to the west. Small reservoirs have been formed by damming these streams, and the water used to irrigate a part of the flat area. The Ludlow lignitic member of the Lance formation, dipping 8°–10° W., crops out along the western margin of the township in a sandstone-capped ridge. Elsewhere the lower part of the Lance is the surface formation. Although the structure is obscured in the eastern part of the area, it is probable that the rocks there dip

[1] Numbers in text refer to locations on the maps, Plates I and II, and many of them to graphic sections on Plates VI to XI.

eastward, as they do in the township to the north, and that the axis of a gentle north-south anticline crosses the west side of the township. No lignite bed of commercial importance is exposed within the township.

T. 21 N., R. 1 E.

The surface of T. 21 N., R. 1 E., is roughly rolling, with small areas of barren badlands and many rather prominent clinker-capped buttes. The clinker is the result of the burning of lignite and is the most resistant rock in the region. The lower part of the Lance formation forms the surface rock, and the strata dip gently southeastward.

Of the two lignite beds present the lower and more persistent one is thin and of no value. At location 6, in sec. 4, it is represented by 5 feet of brown shale and carbonaceous shale interbedded, and at location 7, in the NE. ¼ sec. 4, the following section was measured:

Section of lignite beds at location 7, in the NE. ¼ sec. 4, T. 21 N., R. 1 E.

	Ft.	in.
Shale.		
Lignite, dirty	1	6
Shale	2	0
Lignite	1	8
Clay, shaly	6	0
Lignite	1	7
Shale.		
Total section	12	9
Total lignite	4	9

The upper and thicker bed has burned, forming high clinker-covered buttes in secs. 8 and 9 and also in the southeastern part of the township, where a small area under thin cover remains unburned. Section 5, Plate VII, was measured in sec. 23, where the bed outcrops near the top of a hill. At this point there are two beds 3 feet 5 inches and 1 foot 9 inches thick, separated by 2 feet 10 inches of shale.

T. 22 N., R. 1 E.

The surface of T. 22 N., R. 1 E., is rolling prairie interrupted by small areas of barren badlands and many prominent clinker-capped buttes. The northwest half drains into Big Boxelder Creek and the remainder directly into Little Missouri River. All the strata which outcrop in the township belong to the lower part of the Lance formation. There are three beds of lignite, the two upper being the same as those which outcrop in T. 21 N., R. 1 E. The lowest was measured only at location 8, in the SW. ¼ sec. 24, where it is 1 foot thick. The middle bed, which corresponds to the lower bed in T. 21 N., R. 1 E., is burned in most of the area, but is preserved under cover in secs. 9, 10, 11, 15, 33, 34, and 35. A section measured in the SE. ¼

sec. 9 (No. 8A, Pl. VII) shows the bed to contain 3 feet 4 inches of dirty lignite. The upper bed is entirely burned, but its former position is shown by the abundant clinker on the buttes in secs. 10, 11, and 15.

T. 23 N., R. 1 E.

Big Boxelder Creek, which drains a large area in Montana, meanders across T. 23 N., R. 1 E., in a broad valley. High cut banks border the creek in many places, but in other parts of the township the land is rolling and rock exposures are confined to a few small areas of badland. The strata of the Lance formation which constitute the surface rocks of the township appear to be horizontal, or to dip almost imperceptibly eastward, except along the west margin, where there is a distinct westerly dip. This dip may be a part of the same structural feature as that which appears in the townships to the south.

A few thin beds of lignite are scattered throughout the Lance but are too thin to be of value in this township.

T. 16 N., R. 2 E.

The surface in the southern part of T. 16 N., R. 2 E., is rolling, but farther north there is an abrupt rise to the level-topped West Short Pine Hills mesa, which occupies the north-central part. Several low ridges slope gently away from the mesa.

The Pierre shale crops out in a rolling plain in the southwest corner and is surrounded by a belt of sandy slopes weathered from the Fox Hills sandstone. The Lance formation, which overlies the Fox Hills and weathers into sandy, rolling prairie, with small patches of badland, is in the Short Pine Hills overlain unconformably by the White River formation. The thick-bedded Arikaree (?) sandstone, which protects the soft White River formation from erosion, is the cap rock of the mesa.

No bed of lignite outcrops in the township, but a bed of hard black bituminous clay exposed in sec. 23 was once mistaken for coal, and an entry was driven on it several feet into the hill.

T. 17 N., R. 2 E.

The small town of Harding lies in sec. 35, T. 17 N., R. 2 E., in a beautiful, gently rolling valley, which Gen. Custer named Pleasant Valley. The best farming land of this part of the field is in this valley, between the two Short Pine Hills mesas. To the southwest the western mesa rises about 400 feet above the general level of the surrounding prairie. The cliff that bounds the mesa on all sides is composed of the Arikaree (?) sandstone, perhaps 50 feet thick, and the slopes below it of the flesh-colored clay and conglomeratic white sandstone of the White River formation. The lower part of the Lance formation outcrops at the foot of the mesa and forms the sur-

face rock of most of the township. It weathers to a sandy soil. The strata are either level or dip very gently to the northeast.

A few lenses of lignite were observed in the Lance formation in this township, but none are of sufficient thickness to warrant mapping.

T. 18 N., R. 2 E.

The divide between the drainage of Little Missouri River and that of the South Fork of Grand River crosses the northeast corner of T. 18 N., R. 2 E. West of the divide the land slopes gently to Valley Creek, but on the east there is an area of pronounced badlands. Strata of the Lance formation constitute the surface and contain several beds of sandstone but no important bed of lignite. The strata dip very gently to the northeast.

T. 19 N., R. 2 E.

In T. 19 N., R. 2 E., the land is low and flat immediately adjacent to Little Missouri River, which flows along the west line of the township, but to the east the surface rises in gentle undulations to the divide between Little Missouri and Grand rivers. The rugged badlands which characterize the east side of this divide are in marked contrast with the rolling topography on the west. Strata of the lower part of the Lance formation outcrop throughout the area, but the rock structure is almost entirely obscured by a heavy mantle of soil.

A few thin lenses of lignite occur in the lower half of the Lance formation. The most extensive bed is exposed in a badland scarp in sec. 26, where the lignite is burned for almost half a mile along the outcrop, so that only a single section is exposed.

Section of lignite bed at location 9, in sec. 26, T. 19 N., R. 2 E.

	Ft.	in.
Shale, sandy.		
Lignite, dirty		3
Lignite	2	0
Clay.		
	2	3

T. 20 N., R. 2 E.

West of Little Missouri River the surface of T. 20 N., R. 2 E., is low and level, but to the east it is rolling, with a few rocky points on the divides. The Lance, the only formation that outcrops in the township, is composed largely of soft clayey shale but contains a few lenticular beds of sandstone, much carbonaceous shale, and a few thin lenses of lignite. Throughout a large part of the township the rock structure is obscured by the mantle of soil and grass, but in the northeastern part the beds dip noticeably to the west and northwest, although the degree of dip is in most places small.

The lowest lignite bed is exposed in a cut bank of the river in sec. 4, where sections 14 and 15 of Plate VII were measured. The bed is

covered by alluvium, and as it does not outcrop elsewhere it is presumed to be a local lens, such as are common in the Lance formation. In the C Y mine (location 14) an open pit worked in the winter to supply ranchers near by with fuel, the bed is 3 feet 4 inches thick and has a thin shale parting near the middle. At location 15 the bed is more than 3 feet 8 inches thick. Several beds occur above this in sec. 10, as is shown by section 12 (Plate VII). The outcrops of the highest and the lowest beds were mapped as far as they could be traced. The uppermost bed at this point contains 3 feet 7 inches of dirty lignite. The lowest is being mined and contains good woody lignite 2 feet 3 inches thick. The same bed is mined at location 13, in sec. 10, where the following section was measured:

Section of lignite bed at location 13, in sec. 10, T. 20 N., R. 2 E.

	Ft.	in.
Shale and lignite interbedded	1	8
Lignite, dirty		11
Lignite	1	7
Clay.		
Total section	4	2
Total lignite	2	6

At location 10, in the SE. ¼ sec. 14, two beds are exposed. The upper one, which is 2 feet 8 inches thick, is correlated with the upper bed at location 12 and is too dirty to be of value; the lower one is only 1 foot 4 inches thick. At location 16, in sec. 3, the lower bed is 1 foot 4 inches thick, but farther north it is not exposed. At location 11, in the NE. ¼ sec. 13, a strip pit has been opened on a bed that shows the following section:

Section of lignite bed at location 11, in the NE. ¼ sec. 13, T. 20 N., R. 2 E.

	Ft.	in.
Shale, carbonaceous, with thin streaks of lignite	1	6
Shale		7
Shale, carbonaceous, with thin streaks of lignite	1	10
Lignite, extremely dirty	1	0
Lignite, fair	1	8
Clay.		
Total section	6	7
Total lignite	2	8

T. 21 N., R. 2 E.

Little Missouri River, which has a narrow flood plain and several high cut banks, meanders across the middle of T. 21 N., R. 2 E., from south to north. The rest of the township is hilly and locally dissected into badlands, with clinker-capped buttes as minor but striking features. Willet post office, on the stage route from Camp Crook to Bowman, is in sec. 4. All the outcropping rocks belong to

the Lance formation, which is made up of somber-colored clay, sandstone lenses, and soft shale, with numerous beds of carbonaceous shale and thin lenses of lignite. The strata are nearly horizontal in most of the township, but in secs. 8, 9, and 10 they dip locally 4° W.

At location 19 three thin lenses of lignite appear in a cut bank of the river. Only the middle and thickest one is shown on Plate VII. Above this group is a bed which is thicker and more persistent than most lignite beds in the lower part of the Lance formation. At location 17, in sec. 36, it is represented by 2 feet of dirty lignite; at location 39, in sec. 30 of the township to the east, the bed is 3 feet 10 inches thick. (See Pl. VII.) At location 18, in sec. 23, the bed occupies a small area near the top of a high butte and is 4 feet thick. In sec. 14 the bed is burned over a considerable area. At location 40, in sec. 18 of the township to the east, the bed is 4 feet 7 inches thick, and at location 21, in sec. 12, it is represented by 3 feet of carbonaceous shale, with no lignite. Section 20, Plate VII, represents strata exposed on the side of Lola Butte, including this bed and other thin beds above it. At location 22 the bed is 4 feet 3 inches thick, but at location 23, in sec. 3, it is composed of only 2 feet 11 inches of dirty lignite at the top, separated by 1 foot 6 inches of shale from 1 foot of good lignite. West of the river, in sec. 5, the same bed is represented by section 25, Plate VII. No exposures were found in the vicinity of sec. 18, but, to judge from the thickness at location 25 and the small amount of baking caused by the burning of the bed farther south, it is probably too thin to be of value. The same bed is also exposed at several places in the township to the north, but it is thin and unimportant. In the northwestern part of the township a few high buttes are capped by a heavy bed of clinker formed by a burned lignite bed which occurs at a higher horizon. At location 26, in sec. 5, a bed which may correspond to one of the lower beds contains several thin benches of lignite, with a total thickness of 1 foot 10 inches.

T. 22 N., R. 2 E.

Little Missouri River flows northward across the western part of T. 22 N., R. 2 E. Except in the narrow valley of this stream the surface is rolling and grass-covered, with small areas of sandy flats in the northeastern part. The lower part of the Lance formation outcrops throughout the township, except in sec. 1, where a small area of Fox Hills sandstone is exposed. The Lance is mostly sandy and contains one bed of lignite. The rocks dip gently westward, except for a local southeast dip in sec. 25.

The thick lignite bed which outcrops in the township to the south is exposed at location 24, near the southwest corner of sec. 36, where it is but a few inches thick, and at location 31, in the southeast corner of sec. 25, where it contains only 1 foot of lignite. A small

area west of the river is underlain by the same bed, which is here much thicker (3 feet to 5 feet 9 inches), as shown by sections 28, 29, and 30, Plate VII.

T. 23 N., R. 2 E.

T. 23 N., R. 2 E., drains into Little Missouri River, which meanders northward across the west side of the township. Within the meanders are sandy alluvial flats, and the valley is bordered by barren hilly areas. In the eastern part there is a low and rather smooth area underlain by the Fox Hills sandstone and fringed hills characteristic of the Lance formation. Only the very top—perhaps 20 feet—of the Fox Hills sandstone is exposed, and the area covered by it is along the axis of the Glendive anticline, which extends northwest to Glendive, Mont.

Only one section of lignite was measured, in the west bank of the river at location 32, in sec. 19, At this place the bed is 10 inches thick.

T. 16 N., R. 3 E.

The East Short Pine Hills mesa, which occupies a considerable area in the northeastern part of T. 16 N., R. 3 E., rises abruptly to an elevation nearly 500 feet above the surrounding prairie and forms one of the prominent landmarks of this part of the field. The top of the mesa is grass covered and its sides are clothed by an abundant growth of small pine trees, from which is derived the name Short Pine Hills. Away from the mesa the surface of the township is undulating and grass-covered, except in a narrow area about the edge of the mesa, where rocks slumped from the cliff have been dissected by recent erosion into intricate badland forms.

The soft somber-colored sandy shale of the lower part of the Lance formation forms the surface of the township, except in the Short Pine Hills, where it is overlain unconformably by the White River and Arikaree (?) formations. The White River is composed of soft greenish and gray marl and sandstone about 100 feet thick and contains numerous fossil bones. The Arikaree (?), which forms the cap rock of the mesa, consists of greenish-gray sandstone with some conglomerate, at least 75 feet thick.

The rocks exposed in this township do not contain important beds of lignite anywhere within its limits.

T. 17 N., R. 3 E.

The East Short Pine Hills, which rise nearly 500 feet above the surrounding area, occupy the southeast corner of T. 17 N., R. 3 E., and are surrounded by a mass of rocks slumped from the edge of the mesa. The divide between the eastward drainage of the South Fork of Grand River and the northward drainage of Little Missouri River extends northward from the Short Pine Hills for 3 miles and

then northwestward. The crest of the divide is a sharp line between areas showing topography of two different types. On the west is an undulating prairie; on the east is a strip of almost impassable badlands locally known as the Jump-off, with sharp ridges, deep gullies, and isolated buttes.

The Arikaree (?) sandstone caps the Short Pine Hills mesa and in places forms an impassable cliff more than 100 feet high. Below this sandstone the soft rocks of the White River formation are exposed in the steep slopes of the hills. A remnant of the White River formation occupies a small area in secs. 13 and 24. The surface rocks of the remainder of the township belong to the lower part of the Lance formation, which in this area contains numerous carbonaceous beds in addition to the usual somber-colored clay and friable sandstone. The strata dip gently to the northeast.

Several thin beds of lignite outcrop in the badlands east of the divide, but only one attains sufficient thickness to warrant mapping. At location 33, in the SE. ¼ sec. 13, 1 foot of lignite is exposed. The same bed at location 34, less than three-quarters of a mile to the north, contains 2 feet of lignite. Except at these two localities, however, the bed is not known.

T. 18 N., R. 3 E.

The divide between the South Fork of Grand River and Little Missouri River crosses the southwest corner of T. 18 N., R. 3 E. To the west the land is rolling and grass covered, but to the east, for 2 or 3 miles, the area is deeply dissected into pronounced badlands, locally known as the Jump-off. The Lance formation, composed of somber-colored sandy clay with scattered ferruginous sandstone concretion-like masses, outcrops throughout the whole township, and the strata dip gently northeastward. No lignite bed of importance is exposed in the township.

T. 19 N., R. 3 E.

The Jump-off, with its deeply dissected badlands, continues northward through T. 19 N., R. 3 E., and occupies the eastern three-fourths of it, but west of the badlands the grass-covered surface slopes gradually toward Little Missouri River. A few high points on the divide are capped by a light-yellow friable sandstone belonging in the Ludlow lignitic member of the Lance formation. An interesting slump of rocks of the White River formation is to be seen in sec. 17, partly on top of the divide and partly in a gully to the east. The age of the rocks involved in the slump is proved not only by their color and composition but also by the fossils they contain. Their presence in this isolated area, together with other masses in place on the Short Pine Hills, Slim Buttes, and elsewhere, indicates that the White River formation once covered a large part of the field. The

beds of the Lance formation dip gently to the northeast. The positions of the outcrops of three small lenses of lignite are shown on Plate I (in pocket). The lowest, at location 36, in sec. 9, is 1 foot 9 inches thick, but its horizontal extent is not great. Just below the base of the Ludlow lignitic member of the Lance is a more persistent bed, exposed in secs. 8, 9, 19, 20, and 30. At location 35, in sec. 19, this bed is represented by 3 feet 2 inches of carbonaceous shale with thin streaks of lignite. At location 37, in the NW. ¼ sec. 9, there is 1 foot 8 inches of good woody lignite at this horizon. Several lignite beds having thicknesses of less than 1 foot 8 inches are exposed in the badlands but are not of sufficient importance to show on the map.

T. 20 N., R. 3 E.

The surface of T. 20 N., R. 3 E. is rolling prairie, but the eastern third is interrupted by badlands. The surface rocks of the township belongs to the Lance formation and dip gently northeastward.

Lenses of lignite, mostly less than a foot thick, are found at several places, but none worthy of mapping was noticed in this area. Along Gallup Creek, in sec. 20, a bed of lignitic shale with streaks of lignite has burned to form a thin clinker. On the line between secs. 27 and 28 is a prominent butte capped with clinker from a bed which is not under cover in this township, but probably corresponds to the bed exposed at locations 35 and 37, in the township to the south.

T. 21 N., R. 3 E.

The surface in the western and northeastern parts of T. 21 N., R. 3 E. is mostly gently undulating and grass covered, but small clinker-capped buttes rising here and there form conspicuous landmarks. In the southeastern part of the township the surface is rather rough. The higher portions of the divide are capped by the Ludlow lignitic member of the Lance formation, and the lower part of the Lance is the surface rock over the rest of the township. The strata are nearly level along the west side and dip gently eastward in the eastern half.

Lignite is exposed at several places in the township and has been mined on a small scale at three localities. The lower bed, which contains the best lignite, crops out in the two deepest valleys crossing the west township line. The lignite has been mined for local use at two places, and secs. 39 and 40 (Pl. VII), show it to be of good quality and thickness at each place. The main outcrop of this bed is in the township to the west (T. 21 N., R. 2 E.), and the description of that township gives more information concerning it. A bed of woody lignite 1 foot 3 inches thick outcrops at location 38, in sec. 35, on the east side of the divide, and may be the same bed. By stripping off the overburden a few loads of fuel have been mined for local use at this place. A lignite bed is exposed in several places at the base of the Ludlow lignitic member of the Lance formation. The bed has

burned in secs. 3, 10, 11, 18, and 19, and its former extent is indicated by several clinker-capped buttes. At location 41, in sec. 14, it is represented by 2 feet of dirty lignite.

T. 22 N., R. 3 E.

The rolling and grass-covered surface of the southern part of T. 22 N., R. 3 E., is interrupted in sec. 33 by a small area of badlands. The central and northwestern parts are characterized by sand dunes, open flats, small playas, and a few bare "mud" buttes. In the northeastern part, which is higher, several clinker-capped buttes stand out in marked contrast to the surrounding plains. A spur of Table Mountain extends from the east into sec. 12.

The Fox Hills sandstone, which forms the surface rock in a small area in secs. 5, 6, 7, and 8, is the oldest formation exposed in the township. Peculiar sandy flats and sand dunes are the result of its disintegration. Overlying the Fox Hills, and apparently conformable with it, is the Lance formation, which is composed of somber-colored shale with a few lenticular beds of yellow sandstone and lignite. The upper part of the Lance (Ludlow lignitic member) is more sandy and contains numerous lignite beds of varying thickness and extent. A small thickness of the upper member remains in the higher buttes and ridges.

Although there are a very few exposures from which to judge the geologic structure, such data as are at hand point to the conclusion that the Glendive anticline described by Calvert[1] is represented here by very low dips in a southwest direction.

Near the base of the undifferentiated part of the Lance, at location 43, in sec. 8, there is a bed of lignite 1 foot thick. This bed, however, is only a small lens which does not extend over any considerable area. At location 42, in sec. 21, about 100 feet higher in the formation, there is a lens of lignite less than a foot thick. At the base of the Ludlow lignitic member of the Lance there is a variable unimportant lignite, as shown by the following sections, taken at locations 44, 45, and 46:

Sections of lignite bed in T. 22 N., R. 3 E.

Location 44. SW. ¼ sec. 12.

	Ft.	in.
Clay.		
Shale, lignitic		8
Lignite, extremely dirty	1	8
Clay		
Total section	2	4
Total lignite	1	8

Location 46. SW. ¼ sec. 1.

Shale.		
Lignite	1	10
Clay.		

Location 45. NW. ¼ sec. 2.

	Ft.	in.
Clay.		
Lignite		1
Clay		1
Lignite		2
Bone		3
Lignite	1	1
Clay		1
Lignite		4
Clay.		
Total section	2	1
Total lignite	1	8

[1] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, p. 201, 1912.

A still higher and more valuable bed is present in the NE. ¼ sec. 12. The bed has been burned in part of the area, and its outcrop is concealed elsewhere by talus from the cliff of the mesa just east of the township. To judge from the character of the fusion produced by the burning, it is probable that this bed is more than 3 feet thick. A clinker bed which caps several high buttes in secs. 1, 11, and 12, is probably due to the burning of this bed.

T. 23 N., R. 3 E.

The surface of T. 23 N., R. 3 E., is similar to that of surrounding areas. The Lance is the surface formation of the township, except in the southwest corner, where a small area of the underlying Fox Hills sandstone is exposed. The rocks dip gently to the east, in accordance with the general anticlinal structure which is described in the discussion of T. 23 N., R. 2 E.

Along a badland scarp in sec. 30 a thin lens of lignite, showing the following section, is exposed in the lower part of the Lance:

Section of lignite bed at location 47, in the NE. ¼ sec. 30, T. 23 N., R. 3 E.

	Ft.	in.
Clay, gray.		
Bone, with thin lenses of lignite		11
Lignite, with shiny luster		10
Clay		4
Lignite		1
Clay		1
Lignite		4
Clay.		
Total section	2	7
Total lignite	1	3

At the base of the Ludlow lignitic member of the Lance is a variable bed of lignite, which has burned along its outcrop in secs. 21 and 22. In the SW. ¼ sec. 22 the following section is exposed:

Section of lignite beds at location 48, in the SW. ¼ sec. 22, T. 23 N., R. 3 E.

	Ft.	in.
Shale, brown.		
Shale, carbonaceous, with thin streaks of lignite	2	6
Clay		5
Shale, carbonaceous		4
Lignite		10
Clay	15	0
Shale, lignitic		4
Lignite		11
Clay.		
Total section	20	4
Total lignite	1	9

The lower bed of lignite represents the base of the lignitic member of the Lance.

T. 16 N., R. 4 E.

The eastern and southern parts of T. 16 N., R. 4 E., are in most places rolling and grass covered, but a few high rocky points rise above the general level of the prairie and form conspicuous landmarks. The spur from the East Short Pine Hills in sec. 7 and an outlying butte in sec. 8 are the most prominent points. Between this butte and the mesa to the west is an area of rough badlands.

The Lance, which is the surface formation of most of the township, is composed largely of somber-colored sandy shale with lenticular beds of sandstone and in places thin beds of lignite. This formation is succeeded on the slopes of the mesa and butte by clay and marl of the White River formation, and these are in turn overlain by the Arikaree (?) sandstone, which forms the prominent cliff. The strata dip slightly northeast. In this township no lignite of value is exposed.

T. 17 N., R. 4 E.

The Jump-off, which in T. 17 N., R. 4 E., marks the north side of the divide between Moreau River and the South Fork of Grand River, extends across the southern part of the township. At many places along the northeast side of the divide there is a precipitous scarp with steep ridges and bare "mud" buttes carved from the soft shale of the lower part of the Lance formation. In the northeastern part of the township the land is rolling and grass covered.

The lower undifferentiated part of the Lance formation constitutes the surface rock of the entire township, but the structure is almost wholly obscured by the sand and soil. No lignite of sufficient thickness to warrant mapping is exposed, but thin beds are present at several places in the badlands.

TPS. 18 AND 19 N., R. 4 E.

The surface of Tps. 18 and 19 N., R. 4 E., is characterized by low grass-covered hills and sandy flats sloping gradually toward the South Fork of Grand River, which flows through the southern part of T. 19 N. and drains the entire area. Several "mud" buttes rise as prominent landmarks above the surrounding flat and present a striking contrast to the general rolling topography of the region. A few small areas of badlands are present in the northern part of T. 19 N. and in the extreme southwestern part of T. 18 N.

The soil, which is the result of the disintegration of soft sandy shale and sandstone of the lower part of the Lance formation, is adapted to agriculture, as is shown by the large number of prosperous settlers who live in the area. That the rocks dip gently to the southeast is assumed from the general structure of the region and from a few isolated exposures in the township. No bed of lignite thick enough to warrant mapping is exposed, but there are thin beds at a number of places in the badlands.

T. 20 N., R. 4 E.

Several high, steep-sided buttes along the divide south of Jones Creek in T. 20 N., R. 4 E., and the township to the east stand out above the general rolling grass-covered surface as the most prominent topographic features of the area. The bright-red clinker which caps these buttes and which is the result of the burning of a thick lignite bed is very conspicuous and forms the most resistant member of the rock series in this part of the field. Jones Creek, one of the few perennial streams of the region, drains a large part of the township and occupies a comparatively narrow valley through which it flows in intrenched meanders.

The Lance formation outcrops through the entire area. The lower part is composed largely of soft somber-colored shale and clay, in which occur numerous hard, concretion-like masses of sand. The formation contains numerous fossil remains of such animals as Triceratops, Trachodon, Champsosaurus, and Aspideretes, the bones of which appear scattered over the barren surface at a number of localities. Along the divides and higher areas of the townships the Ludlow lignitic member of the Lance is exposed in considerable thickness and contains beds of lignite of more or less value. The clinker caused by the burning of one of these lignite beds forms the cap rock of several prominent buttes in the central part of the township. A section of the rocks exposed in this part of the field is given on pages 20–21.

At the base of the Ludlow lignitic member is a bituminous shale which locally contains thin lenses of lignite. At locations 52 and 53, in sec. 35, there is about 1 foot of lignite, and at location 54, in sec. 26, several feet of dark-brown shale, with a few inches of lignite, occurs at the same horizon. In sec. 16 the following beds are exposed:

Section of lignite bed at location 55, in the SE. ¼ sec. 16, T. 20 N., R. 4 E.

	Ft.	in.
Clay.		
Shale, bituminous	0	2
Lignite	1	11
Shale	1	1
Lignite	1	4
Clay.		
Total section	4	6
Total lignite	3	3

The lignite is of good quality. At location 59, in sec. 5, there is only 1 foot of lignite at this horizon.

Above this there are two other beds of lignite of varying thickness and quality, as well as several bands of carbonaceous shale. Section 51 (Pl. VII) represents both beds, each of which is about 5 feet thick and extremely dirty. Below the lower bed and separated from it by 2 feet 9 inches of shale is a local bed 2 feet 7 inches thick. At loca-

tion 50, a few yards west of location 51, the lower bed is 3 feet thick and much better in quality and has been mined for local use. Sections 56 and 58 (Pl. VII) represent the main lower bed as exposed in two small buttes in secs. 14 and 24. The total thicknesses of the bed at these places are 6 feet and 5 feet 7 inches, respectively. The clinker that caps these buttes is the result of the burning of the upper bed. Along the sides of the butte, in sec. 27, the bedrock is obscured by débris from the overlying rocks and no bed of lignite is exposed, although such a bed may be present.

T. 21 N., R. 4 E.

The land in the valley of Bull Creek in the north half of T. 21 N., R. 4 E., is rolling and grass-covered but rises rather abruptly to the high divide to the south. Beyond the divide the surface slopes gently toward Jones Creek, which flows eastward across the township south of this one. The South Cave Hills (see Pl. III, *A*, p. 10) in the southeastern part of the township, form one of the most prominent topographic features of the field. They rise abruptly 250 to 300 feet above the general level of the plains, and occupy a large area in this and adjacent townships. The massive light-brown or yellowish sandstone, which in places is as much as 80 feet thick, stands out as a sheer cliff at the top of the mesa, and in this township is the only representative of the Fort Union formation. Beneath this sandstone is a succession of sandy shale, sandstone, and lignite beds that are referred to the Ludlow lignitic member of the Lance formation. In this part of northwestern South Dakota the more valuable beds of lignite occur in this member. The lower part of the Lance outcrops in the valleys of Bull Creek and Jones Creek.

Lignite beds of varying thickness, quality, and extent are exposed in this township. The thickest and most extensive bed is in the Ludlow lignitic member and outcrops well up on the side of the South Cave Hills mesa. Its topographic location has probably prevented its exploitation. The only bed from which lignite has been mined is near the top of the lower part of the Lance and outcrops along the valley of Bull Creek.

The exact correlation of the several sections measured in this township is difficult because of the lack of exposures and the variability of the lignite beds. Four valuable beds in the Ludlow member of the Lance are exposed at location 70, in the north face of the South Cave Hills, but at no other place in the township is there so complete a section revealed.

Three sections in secs. 14 and 15 represent the lowest beds exposed. At each of locations 90A and 91, in the NW. ¼ sec. 14, 2 feet of dirty lignite occurs. It is probable that the upper and lower beds at location 80 are the same as those at locations 90A and 91, respectively.

Sections of lignite beds at location 80, in the NE. ¼ sec. 15, T. 21 N., R. 4 E.

	Ft.	in.
Shale and clay.		
Lignite	1	11
Clay, gray	7	0
Shale, brown		6
Lignite	1	4
Clay.		
Total section	10	9
Total lignite	3	3

Above these beds and near the top of the lower part of the Lance formation is a bed which has considerable extent, but is not thick enough to be of much value. Its maximum thickness (4 feet 6 inches) is exposed at location 90, in the NE. ¼ sec. 14, but a short distance to the north, at location 88, the bed is split into three benches by thin shale partings. (See Pl. VII.) Sections measured at locations 78, 79, and 92 are shown graphically on Plate VII, but at other places the bed is thin, as is shown by the following sections:

Sections of lignite bed 4 feet below the top of the lower part of the Lance formation.

Location 73. SW. ¼ sec. 28.

	Ft.	in.
Clay.		
Shale, carbonaceous		8
Lignite	1	2
Shale.		
Total section	1	10
Total lignite	1	2

Location 75. SE. ¼ sec. 21.

	Ft.	in.
Clay, sandy.		
Lignite, poor	1	8
Shale	2	11
Lignite, poor		6
Lignite	1	10
Shale.		
Total section	6	11
Total lignite	4	0

Location 76. SW. ¼ sec. 22.

	Ft.	in.
Clay, sandy.		
Lignite	1	3
Shale, brown		2
Shale, carbonaceous		8
Lignite	1	0
Shale.		
Total section	3	1
Total lignite	2	3

Location 77. SW. ¼ sec. 22.

	Ft.	in.
Lignite	1	7

At the base of the Ludlow member of the Lance there is a thin bed which was mapped in secs. 30, 31, and 32, and along the northwest side of the South Cave Hills. It was examined at locations 60, 61, 74, 81, 82, 83, 84, 85, and 89, and all the sections except those at locations 60 and 89 are shown graphically on Plate VII. At location 60, in sec. 32, the bed contains only 6 inches of lignite, and at location 89, in sec. 13, it is represented by nothing but shale.

In the side of the South Cave Hills mesa within a stratigraphic distance of less than 100 feet there are at least four beds of lignite, as shown by section 70 (Pl. VII). The lowest bed is exposed at locations 68, 70, 71, and 72 and ranges in thickness from 9 feet 6 inches at location 72, in the SE. ¼ sec. 25, to 1 foot 2 inches at location 68,

in the SW. ¼ sec. 23. At location 71 it is represented by about 4 feet of weathered lignite. The next higher bed, shown in sections 69, 70, and 86 (Pl. VII), is 15 feet above the lowest bed at location 70 and ranges in thickness from 2 feet 6 inches at location 86 to 5 feet 5 inches at location 69. About 12 feet above this bed is a third bed, represented by secs. 62, 63, 65, 66, 67, 70, and 87, (Pl. VII), which is the only persistently thick bed outcropping in this township. Its thickness ranges from 4 feet 1 inch at location 70 to 8 feet 9 inches at location 66. The highest bed is partly exposed at only one place in this township. (See section 64, Pl. VII.)

T. 22 N., R. 4 E.

Table Mountain, a high mesa with rocky slopes similar to those of the Cave Hills, occupies the northwest corner of T. 22 N., R. 4 E. This mesa and a series of high buttes along the divide to the southeast form prominent landmarks of the region, rising several hundred feet above the surrounding country. Surrounding the mesa is an area of rather elevated rolling grass-covered country where the soil is fertile enough to attract numerous settlers, who can, by dry-farming methods, raise good crops of small grains, potatoes, flax, etc. Most of the area is drained toward the southeast by two small streams that occupy broad, open valleys, but the northeastern part is drained eastward by Crooked Creek. The Fort Union formation is represented in this township by the sandstone that caps Table Mountain and several isolated buttes to the south. Beneath this sandstone there are exposed friable yellow sandstone and sandy shale, containing numerous carbonaceous and lignitic beds. These rocks are referred to the Ludlow lignitic member of the Lance formation. The upper part of the somber-colored shale which constitutes the lower part of the Lance is exposed in the deeper valleys. The rocks dip uniformly to the east at about 45 feet to the mile.

The lowest lignite bed exposed is in the Lance formation at location 93, in sec. 33.

Section of lignite bed at location 93, in the SE. ¼ sec. 33, T. 22, N., R. 4 E.

	Ft.	in.
Sand, yellow.		
Lignite, dirty, variable in thickness		4
Clay	2	0
Lignite	2	2
Clay.		
Total section	4	6
Total lignite	2	6

This bed is only a small lens, but a strip pit has been opened on it and lignite is being mined for local use.

In this township, as in other parts of the field, a thin bed is present in some places at the base of the Ludlow member of the Lance. At

location 94, in the SW. ¼ sec. 34, there is 1 foot 1 inch of good lignite; at location 119, in the NE. ¼ sec. 18, 2 feet; and at location 113, in sec. 13, the bed is thin and badly split up by partings, as is shown by the following section:

Section of lignite bed at location 113, in sec. 13, T. 22 N., R. 4 E.

	Ft.	in.
Shale.		
Lignite		8
Clay		1
Lignite		5
Shale		1½
Clay		3
Lignite		8
Clay.		
Total section	2	2½
Total lignite	1	9

The most persistent and thickest bed exposed in this township is less than 50 feet above the base of the Ludlow member. In several small isolated areas at locations 95, 96, and 97, in secs. 27, 34, and 35, the bed is under a rather thin cover. At location 97 it contains only 2 feet 2 inches of poor lignite, but at the other two locations the bed is more valuable. (See Pl. VII.) In sec. 28 the bed has burned and the resulting clinker caps a large low butte. At locations 98 and 99, in sec. 17, measurements show 4 feet and 4 feet 2 inches of lignite, respectively, and at location 99 a strip pit has been opened and lignite mined for local use. No good exposures were found in secs. 7, 8, or 9, the 1 foot 6 inches of lignite exposed at location 110 probably representing only the upper part of section 99. Sections 103, 104, 105, 106, 107, 108, 111, 123, and 124, on Plate VII, show the character of the bed where exposed in the northern part of the township, the maximum thickness being more than 8 feet at location 105, in sec. 12. Some lignite has been mined from this bed for local use at location 103, in the NE. ¼ sec. 24, and at location 123, in the NE. ¼ sec. 6.

A minor lignite bed above this bed crops out in secs. 5, 17, and 20. At location 120 it contains 2 feet 6 inches of poor lignite, and at location 109 there is 2 feet 9 inches of lignite. At location 102, in the SE. ¼ sec. 17, there is 1 foot 8 inches of lignite, but at location 101, in the NW. ¼ sec. 20, the bed is represented by a few inches of carbonaceous shale.

Still another good bed underlies the higher part of the mesa, where its outcrop is usually covered by débris slumped from the rim rocks above. Several measurements were obtained, however, which are shown by sections 100, 112, 114, 115, 117, 118, 121, and 122, on Plate VII. The bed ranges in thickness from 2 feet 9 inches at location 117, to 6 feet 10 inches at location 114. At locations 118 and 122

small strip pits have been opened from which near-by farmers obtain their supply of fuel.

Below the rim rock at location 116, in sec. 8, a 1-foot 9-inch bed of lignite is exposed, but it is probably not persistent.

T. 23 N., R. 4 E.

The western and northern parts of T. 23 N., R. 4 E., are drained by tributaries of the North Fork of Grand River, and the southeastern part by tributaries of Crooked Creek. Sloping away from the comparatively level upland area in the central part of the township is a rolling, grass-covered country, which on the west is somewhat dissected into badlands. A striking topographic feature in the eastern half of the township consists of the large number of reddish hills capped by baked rocks caused by the burning of the main lignite bed.

The eastern two-thirds of the township is well settled, but the western two tiers of sections are for the most part not suitable for farming, as they are decidedly rough and the soil is rather infertile.

The rocks exposed in the township belong to the Lance formation and have a total thickness of about 250 feet. The upper 150 feet contains thin beds of lignite which, in the main, are of little value and in places merge horizontally into brown carbonaceous shale. This part of the formation is differentiated as the Ludlow lignitic member. The strata are nearly horizontal but have a slight eastward dip of about 40 feet to the mile.

The only good bed of lignite in this township is in the lower part of the Ludlow lignitic member of the Lance formation. Sections were measured on it at locations 124, 125, 126, 128, 129, 130, 131, and 133. The measurements obtained at these points are shown graphically on Plate VI. The thickest section was that measured at location 131, in a strip pit in the northeast corner of sec. 26, where 7 feet 5 inches of lignite is exposed. The bed at that place is separated by 22 feet of shale with some lignite from a lower bed of lignite about 2 feet 6 inches thick. The same bed is worked in small strip pits at locations 130, 125, and 124, in secs. 22, 29, and 32, respectively. At these places the lignite appears to be of rather low grade and impure, being much broken up by thin shale partings with streaks of dirty lignite. This bed is possibly the same as the one at the Durkin mine, in sec. 34, T. 130 N., R. 103 W., N. Dak. In the eastern part of the township the lignite has burned extensively along the outcrop. The maximum thickness of the strata overlying the bed is 75 feet.

Below the main bed are several beds less than 2 feet 6 inches thick. One of these is exposed in secs. 20 and 21, and at location 132, in the NW. ¼ sec. 21, it has a thickness of 2 feet 1 inch. Another minor bed 45 feet above the main bed is exposed at location 127, in the SW. ¼ sec. 21, where it is 2 feet 6 inches thick.

TPS. 16, 17, 18, AND 19 N., R. 5 E.

The area embraced in Tps. 16, 17, 18, and 19 N., R. 5 E., extends from the southern boundary of the field to a point within about 4 miles north of Buffalo, the county seat of Harding County. For the most part the surface is gently undulating and grass-covered, sloping toward the South Fork of Grand River on the north and toward Moreau River on the south. Areas of migrating sand dunes are common in T. 18 N., and badlands carved from the soft sandy shale of the lower part of the Lance formation occur along the divide between the two drainage systems. A few barren "mud" buttes relieve the monotony of the landscape in the southern part of the area. Except in the part of the area north of South Fork of Grand River, the land is largely unsettled and is used for sheep range. The only permanent stream is the South Fork of Grand River, and even that is nearly dry in the summer season.

The shale of the lower part of the Lance formation occupies the surface of the area, and although there are numerous carbonaceous beds in the formation, at only one place is lignite known to be present. A small strip pit at location 134, in sec. 12, T. 17 N., R. 5 E., has been opened on a bed having a thickness of 1 foot 6 inches and has yielded considerable fuel for the ranchers near by. No appreciable structure is evident in this area.

T. 20 N., R. 5 E.

The surface of the two southern tiers of sections in T. 20 N., R. 5 E., is gently rolling, with a high clinker-capped butte in sec. 30 and a flat-topped butte capped by resistant sandstone in sec. 36. The surface of the rest of the township is roughly rolling, except that part occupied by the Cave Hills and the outlying buttes, which rise about 300 feet above the average surface of the plain. The area is, for the most part, too rough and broken for agriculture and is used almost entirely for stock raising.

Shale of the lower part of the Lance formation crops out in the broad valleys but is succeeded on the divides by the soft sandstone and sandy shale of the Ludlow lignitic member of the Lance. The tops of the mesas and buttes are capped by the lowest sandstone of the Fort Union formation. A small remnant of the White River formation occurs on the top of the mesa in sec. 5. The strata dip gently to the northeast.

Four different beds of lignite are present, but the thickest and most extensive is in the Ludlow lignitic member of the Lance. One drift mine and several strip pits have been operated in this township. The largest operation is at the Hilton mine (see section 144, Pl. VII), in sec. 6, where a drift has been driven 120 feet into the hill on a bed showing the following section:

Section of lignite bed in Hilton mine.

	Ft.	in.
Lignite (roof)	1	11
Shale		6
Lignite (sampled for analysis)	2	10
Shale		1
Lignite (sampled for analysis)	4	4
Shale, reported	2	0
Lignite	2	0
Total section	13	8
Total lignite	9	2

The two middle benches, aggregating 7 feet 2 inches of lignite, are mined; but the upper bench is left for roof. A sample of the lignite was taken for analysis (No. 13221, p. 42) and found to contain a large percentage of ash. At location 141, in sec. 20, the following section on the same bed is exposed in a strip pit:

Section of lignite bed at location 141, in the SW. ¼ sec. 20, T. 20 N., R. 5 E.

Clay, gray to brownish.	Ft.	in.
Lignite, dirty		4
Shale, brown, and gray clay	5	0
Lignite		6
Clay, gray	1	10
Lignite	1	9
Clay, gray.		
Total section	9	5
Total lignite	2	7

Two small strip mines, at locations 137 and 138, have been opened on a bed in the lower part of the Lance, but owing to the thinness of the bed (1 foot 7 inches and 2 feet 4 inches, respectively) the amount of fuel removed from each place has been small. This bed is exposed also at locations 135 and 139, where it has thicknesses of 1 foot 10 inches and 2 feet, respectively.

The carbonaceous bed that marks the base of the Ludlow member of the Lance was examined at two places. At location 136 it is represented by 20 feet of carbonaceous shale with thin streaks of lignite, and at location 142 there is a bed of dark shale several feet thick but no lignite.

The bed opened at the Hilton mine is exposed at two other places (locations 145 and 146), at neither of which is the lignite thick or clean. The following section was measured:

Section of lignite bed at location 145, in the SW. ¼ sec. 4, T. 20 N., R. 5 E.

Shale, brown.	Ft.	in.
Bone, very sandy, purplish, of variable thickness; maximum	3	0
Clay, brown, of variable thickness; maximum	2	0
Lignite, dirty, variable in thickness		8
Shale		4
Lignite	1	6
Shale.		
Total section	7	6
Total lignite	2	2

At location 146, in the NW. ¼ sec. 4, there is only a few inches of lignite in this bed. The lignitic shale at location 143, in sec. 12, is supposed to be at the same horizon. The highest bed outcrops around the butte in secs. 19 and 20, and at location 140 it contains 6 feet 7 inches of impure lignite. Rattlesnake Butte, in sec. 30, is capped by clinker from this bed.

T. 21 N., R. 5 E.

Parts of both the North and South Cave Hills lie in T. 21 N., R. 5 E., the North Cave Hills occupying the northeast corner and the South Cave Hills the southwest corner. Between them are the broad, rolling valleys of Bull Creek and its tributaries Dry and Camel creeks. Bull Creek, one of the few perennial streams of the region, crosses the township from west to east in a broadly meandering course and receives the run-off from the whole area. On both sides of its narrow, steep-sided channel the surface rises in gently rolling, grass-covered slopes to the bases of the mesas.

The Cave Hills mesas cover an area of several square miles and rise several hundred feet above the surrounding country in almost impassable cliffs. In this township several narrow, flat-topped ridges, separated by deep box canyons, extend beyond the main area of the mesas and give the surface a very rugged appearance. A large butte in sec. 18 and two smaller ones in secs. 19 and 20 are capped by the same resistant yellow sandstone as the principal mesas. Below the cap rock of the mesa there is a steep talus slope, on which are large blocks of sandstone, slumped down from the cliff, which make the area almost impassable.

The Lance formation outcrops in the valleys, but the cap rock of the mesas and the prominent buttes belongs to the Fort Union formation. There is a small area of White River formation in secs. 31 and 32. In most places the beds dip northeastward about 50 feet to the mile, but in sec. 24 and in a narrow area to the northwest they dip toward the southwest. The general northeasterly dip apparently prevails in the northeast corner of the township.

Several lignite beds, varying in thickness and quality, outcrop in this township. Because of the variability of the beds and the lack of exposures the exact correlation of beds between sections is in many places very difficult.

The lowest lignite bed is about 50 or 60 feet below the base of the Ludlow lignitic member of the Lance and is the most extensive bed in the township. (Exposed at locations 147 to 159 and 174, Pl. I.) It is at approximately the same horizon as the lowest exposed bed in T. 20 N., R. 5 E. At location 147, in sec. 36, there is no lignite, the bed being represented by several feet of brown and black shale. To the west the bed thickens rapidly, showing 3 feet 9 inches of good lignite at location 148, in sec. 34, where it is mined for local use. (See Pl. VII.)

Up Dry Creek, west of locations 149 and 150, there are no exposures of lignite, but a very small amount of clinker in the northeastern part of sec. 21 probably represents the same bed and it is assumed that the bed is thin or absent west of the center of sec. 21. Along the south side of Bull Creek the bed ranges in thickness from a few inches at location 151 to 1 foot 3 inches at location 152, 2 feet 10 inches at location 153, and 6 feet 5 inches at location 155. North of Bull Creek, at location 157, in sec. 14, there is a small strip pit on the bed, which is here 5 feet 4 inches thick. At location 158 the same bed has a total thickness of 5 feet 11 inches but is dirty and split into three benches. At location 159 it contains only 3 feet 6 inches of dirty lignite. To the northwest, beyond location 157, the outcrop is concealed, but at location 174, in sec. 4, a bed more than 4 feet 9 inches thick is supposed to represent the same horizon. The outcrop of this bed of lignite is particularly well situated for opening extensive strip pits, the most economical method of mining at the present time.

Lignite at the base of the Ludlow lignitic member of the Lance is exposed at two places in the township, where the sections are as follows:

Sections of lignite bed at the base of the Ludlow lignitic member of the Lance formation in T. 21 N., R. 5 E.

Location 183. NW. ¼ sec. 19.

	Ft.	in.
Sand.		
Lignite, dirty	1	5
Lignite	2	0
Clay.		
Total lignite	3	5

Location 184. West side of NE. ¼ sec. 29.

	Ft.	in.
Shale, brown to black.		
Lignite	1	4
Lignite, very dirty	1	2
Clay.		
Total lignite	2	6

A small strip pit has been opened at location 183, but little lignite has been mined from it.

In the South Cave Hills four lignite beds of varying thickness and quality are exposed above the base of the Ludlow lignitic member of the Lance. Although there is more than 3 feet of lignite at two or more places the beds are not regular in thickness and mining has been undertaken only at location 185, in sec. 30. Lack of exposures along the outcrops of the beds prevents exact correlation, but the following statement indicates the approximate relation of sections measured in this part of the township:

Relation of lignite beds in southwestern part of T. 21 N., R. 5 E.

	Feet.
Lignite bed shown in sections 179 and 180, Plate VII, and section 178, page 70.	
Interval	50
Lignite bed shown in sections 188, 189, and 190, page 70.	
Interval	25
Lignite bed shown in sections 181, 182, and 185, Plate VII, and sections 186, 188, and 191, page 70.	
Interval	30
Lignite bed shown in section 185, Plate VII, and section 187, page 70.	

In addition to the sections shown graphically on Plate VII, the following were measured in the southwestern part of the township:

Sections of lignite beds in the southwestern part of T. 21 N., R. 5 E., not shown on Plate VII.

Location 178. SE. ¼ sec. 28.

	Ft.	In.
Shale, sandy.		
Lignite		9
Shale, sandy	4	8
Lignite	1	0
Shale, brown	5	0
Lignite, dirty		8
Shale.		
Total section	12	1
Total lignite	2	5

Location 187. NW. ¼ sec. 30.

Clay.		
Lignite	1	3
Clay	2	11
Lignite		8
Shale		6
Lignite	1	5
Clay.		
Total section	6	9
Total lignite	3	4

Location 186. SW. ¼ sec. 19.

Shale, brown.		
Lignite	2	2

Location 188. NW. ¼ sec. 29.

	Ft.	In.
Lignite	1	10
Sandstone and clay	25	0
Lignite	1	8
Total section	28	6
Total lignite	3	6

Location 189. SE. ¼ sec. 28.

Lignite	1	5

Location 190. SE. ¼ sec. 32.

Clay.		
Shale, lignitic		10
Lignite		9
Clay	3	0
Lignite		10
Shale, brown	4	6
Lignite	1	6
Clay.		
Total section	11	5
Total lignite	3	1

Location 191. SW. ¼ sec. 28.

Lignite	1	0
Shale, brown	1	3
Lignite	1	0
Total section	3	3
Total lignite	2	0

In the North Cave Hills, north of Bull Creek, there are three lignite beds in the Ludlow lignitic member of the Lance, two of which attain a thickness of more than 5 feet, but so far no mines have been opened in this part of the township. The most persistent bed outcrops well up on the side of the mesa, and its exploitation will be attended with difficulty. The outcrops of the beds are in many places marked only by clinker. The following table shows the approximate relations of the beds measured in the northeastern part of the township:

Approximate relations of beds measured in the northeastern part of T. 21 N., R. 5 E.

Lignite bed shown in sections 160, 161, 162, 163, and 165, Plate VII, and sections 166, 167, and 172, page 71.
Interval.
Lignite bed shown in sections 168 and 169, Plate VII, and sections 170, 171, and 173, page 71.
Interval.
Lignite bed shown in sections 175, 176, 177, and 171A, page 71.
Uncorrelated section 164.

The following sections are not shown on Plate VII:

Sections of lignite beds exposed in northeastern part of T. 21 N., R. 5 E., not shown on Plate VII.

Location 164. Sec. 12.

	Ft.	in.
Lignite	2	6

Location 166. Sec. 2.

Lignite	1	9

Location 167. Sec. 2.

Lignite	2	4

Location 170. Sec. 14.

Shale, brown	2	0
Lignite	1	4
Total section	3	4
Total lignite	1	4

Location 171. Sec. 3.

Lignite	1	3

Location 172. Sec. 3.

Lignite	1	0
Clay		7
Lignite	1	0
Total section	2	7
Total lignite	2	0

Location 173. Sec. 2.

Lignite	1	5

Location 175. Sec. 4.

	Ft.	in.
Shale, brown.		
Lignite, dirty	1	5
Shale, sandy	2	6
Lignite, dirty		8
Shale.		
Total section	4	7
Total lignite	2	1

Location 176. Sec. 6.

Shale.		
Lignite, dirty		5
Lignite		5
Shale	3	0
Lignite	1	0
Lignite, dirty		6
Sandstone	6	0
Lignite		9
Shale.		
Total section	12	1
Total lignite	3	1

Location 177. NW. ¼ sec. 16.

Lignite	1	10

Location 171A. Sec. 2.

Shale.		
Lignite, dirty	1	0
Lignite	3	0
Shale.		
Total lignite	4	0

T. 22 N., R. 5 E.

Among the most conspicuous and interesting topographic features in T. 22 N., R. 5 E., are the North Cave Hills, which occupy a large area in the central part of the township along the crest of the divide between the two forks of Grand River. From a distance the hills have the appearance of a single bold mesa rising 300 to 400 feet above the surrounding country, but in reality they are composed of a series of narrow level-topped ridges formed by the dissection of the mesa by narrow-mouthed, canyon-like gullies. The hills are capped by about 200 feet of thick-bedded sandstone, which in most places forms an impassable cliff.

The surface in the northwestern part of the township is rolling, with several red-capped hills and a few low sandstone ridges. The southwestern part is a high ridge between the deep valley of Camel Creek on the north and that of Bull Creek on the south. Several high hills capped by sandstone form part of this divide. The eastern part of the township is low, and its only conspicuous feature is a

number of red-capped hills. The total relief in the township is 450 to 500 feet; the lowest points are near the Riley ranch, in sec. 24, and near Cox post office, in sec. 4, and the highest points on top of the North Cave Hills in secs. 21 and 36, where the altitude is about 3,450 feet above sea level.

The northern and eastern parts of the township are drained by Crooked Creek and its tributaries, and the southwestern part by Camel Creek. Crooked Creek, which is fed by numerous springs that issue from the lignite beds or from the base of the rim rock of the Cave Hills, is one of the few perennial streams of the region. Springs yielding small streams of pure cold water occur near the Cox ranch, in sec. 3, the Craig ranch, in sec. 17, and the Riley ranch, in sec. 24, as well as at other places in all parts of the township. The water from these springs contains little or no alkali, because the rocks from which it issues are calcareous and contain but a very small percentage of alkaline salts. A number of well-known ranches are situated in different parts of this township, and outside of the Sioux National Forest homesteaders have recently taken up claims and are attempting to farm the land.

The lowest rocks exposed in the vicinity of the Cave Hills consist of shale, sandstone, and lignite beds belonging to the Lance formation. The shale is dark in color and somewhat sandy and weathers to a semigumbo soil that supports only scanty vegetation. The rocks are decidedly cross-bedded and vary greatly in composition. The shale contains a large number of iron carbonate nodules of varying size, the largest several inches in diameter. In shape they are roundish, elongated, or flat. These nodules on an oxidized surface are brown to reddish, but on fresh fracture have a light-gray or drab color. The Ludlow lignitic member of the Lance, which includes nearly all of the formation exposed in this township, is more sandy, lighter in color, and more evenly bedded than the lower part of the Lance and contains all the valuable lignite beds.

The Lance formation is overlain by the Fort Union formation, which is composed of 250 to 300 feet of massive sandstones, with about 20 feet of light-colored sandstone near the middle and a thin bed of quartzite near the top. The line between the Lance and the Fort Union formation is placed at the base of the sandstone that forms the rim rock of the Cave Hills.

Two small areas of green conglomerate, each a few square rods in extent, are present in secs. 21 and 28 and are assigned doubtfully to the White River formation. The correlation is based on the lithologic character of the beds, as no fossils were found in them. The conglomerate contains green, reddish, and white pebbles, ranging in size from a quarter of an inch to 1¼ inches, and seems to be entirely

different from anything found in the Fort Union. Fragments of chert similar to those common to the White River formation are associated with the conglomerate rocks.

The beds in general dip about 25 feet to the mile toward the southeast, but a mile north of the Craig ranch the attitude of a lignite bed indicates a slight northerly dip. In the neighborhood of the Riley ranch a bed of lignite apparently disappears beneath the creek bed both above and below the ranch house, thus indicating a slight anticline with the axis running northwest and southeast.

There are, in addition to several thin beds, three valuable beds of lignite, the Riley, the Craig, and the T Cross, which were mapped in detail. The lowest and poorest of these is the Riley; the highest and most valuable the T Cross. The Riley bed is 11 feet 3 inches thick at location 211 (see Pl. VI), near the Riley ranch, in sec. 24, where for many years it has been mined for local use. The lignite is of excellent quality, but the bed appears to be decidedly lenticular, for at location 288, in the SW. ¼ NE. ¼ sec. 18, T. 22 N., R. 6 E., about 1½ miles below the Riley ranch, it has been prospected in the creek bottom and is only 3 feet 4 inches thick. The same bed as exposed farther north (location 287) and west (location 289) is of little value. (See Pl. VI.)

About 50 feet above the Riley bed is the Craig lignite bed, which is exposed at locations 213, 231, and 215, along the east side of the Cave Hills, in secs. 3, 11, and 14. Locations 220, 221, 203, and 204 are thought to be on the same bed. Its thickness ranges from 1 foot 10 inches at location 204, in sec. 34, to 6 feet 11 inches at location 231. Detailed measurements of the bed at these places are given on Plate VI. To the west, in secs. 17 and 18, there are small burns along its outcrop, and still farther west, in the adjacent township, the bed is of little value.

The T Cross bed of lignite occurs about 100 feet above the Craig bed. Its identification from place to place is uncertain, but the correlation as shown on the map (Pl. I, in pocket) seems to be the best that could be made. The bed in the southern part of the township, along Camel Creek and its tributaries at locations 192, 193, 196, 197, 198, 199, 200, 201, 202, and 212, is 3 feet 11 inches or less in thickness, but at location 205A it is 5 feet thick. Along Crooked Creek and its tributaries north and east of the Cave Hills the bed is thicker and better in quality. It ranges in thickness from 9 feet 1 inch at location 209 to 3 feet 6 inches at location 218 and has been mined at locations 209, 208, 219, 218, and 218A. This bed is about 3,050 feet above sea level and dips to the east about 20 feet to the mile. It is correlated with the Giannonatti bed, exposed in T. 21 N., R 7 E., and with the T Cross bed as exposed at Ives, N. Dak.

About 60 feet above the T Cross there is another lignite bed, which, along the east side of the Cave Hills, at locations 226, 227, 228, and 230, ranges in thickness from 2 feet (location 228) to 4 feet 4 inches, but is separated into two benches by 4 inches of shale (location 226). The bed is not exposed to the south unless it is represented by a thin bed which at locations 206, 207, and 205 is from 1 foot to about 2 feet 5 inches thick. Near the ranger cabin at location 216, in sec. 10, 2 feet 5 inches of lignite is exposed, and on the north face of the ridge, at location 223, in sec. 18, there is a bed more than 5 feet thick. The approximate position of the upper lignite is immediately below the cliff. At location 222 6 feet of lignite is exposed in a mass of slumped material, which possibly came from the upper bed. Along the ridge between Camel and Bull creeks a lignite bed 2 feet thick at location 195 and 1 foot 4 inches thick at location 194 is apparently between the T Cross and the upper bed. Detailed measurements of the lignite beds in this township are given on Plate VI.

T. 23 N., R. 5 E.

T. 23 N., R. 5 E., is for the most part drained by Crooked Creek and has a rough surface that culminates in the noted landmark, Eagles Nest. Cox post office is in the SE. ¼ sec. 33.

The Lance formation underlies the township, with the exception of Eagles Nest Butte, and is composed of somber-colored shale interbedded with arenaceous shale and sandstone. The rocks are in many places markedly cross-bedded and show very irregular deposition. On weathering this formation gives rise to a very poor soil. The upper portion of the Lance, the Ludlow lignitic member, is somewhat more sandy than the lower portion and carries the only valuable bed of lignite.

The only representative of the Fort Union formation, a heavy-bedded and resistant yellow to gray sandstone 100 feet thick, caps Eagles Nest, in sec. 27. At some places the sandstone is cross-bedded, and locally it is conglomeratic. On weathered surfaces it is decidedly uneven, with numerous large rounded cavities.

Three beds of lignite crop out in the township. The lowest and thinnest is exposed in a boggy place at location 234, in sec. 22, where an accurate measurement could not be obtained, but it is at least 2 feet 6 inches thick. Elsewhere this bed could not be found. Higher beds underlie small hills northeast of Eagles Nest. At location 233 (see Pl. VI) the following section is exposed:

Section at location 233, in the SW. ¼ sec. 23, T. 23 N., R. 5 E.

	Ft.	in.
Shale, brown, carbonaceous and fissile	1	4
Bone		2
Shale, brown, carbonaceous		1
Lignite	1	4
Shale, black, carbonaceous		1
Lignite	1	9
Shale, brown, carbonaceous	16	10
Shale, brown, carbonaceous and fissile, with lenses of lignite as much as 2 inches thick	1	3
Shale, brown, carbonaceous	8	8
Lignite	3	0
	34	6

A few loads of lignite have been removed from the lower bed at this place. The T Cross bed of lignite crops out in Eagles Nest, and the following section is exposed in a prospect at location 232, on the northern slope:

Section of lignite bed at location 232, in sec. 27, T. 23 N., R. 5 E.

Shale, black, carbonaceous.	Ft.	in.
Lignite, very impure		2
Lignite		11
Lignite, impure		9
Lignite, fair quality	1	8
Shale, dark, sandy.		
	3	6

There are at many localities in the northwestern part of the township large masses of red baked rock, probably formed by the burning of this bed, but coal of this bed underlies only small areas in that vicinity. Direct correlation of the beds exposed at locations 232 and 233 is impossible, because in the intervening area the rocks are badly concealed by grassy slopes.

TPS. 16, 17, 18, 19, AND 20 N., R. 6 E.

The entire area of Tps. 16, 17, 18, 19, and 20 N., R. 6 E., with the exception of T. 16 N. and part of T. 17 N., which are drained by Moreau River, lies in the valley of South Fork of Grand River and its tributaries Squaw, Sandy, Jones, and Bull creeks. South of the South Fork of Grand River the surface rises gradually in a sandy, more or less grass-covered plain to the divide in the southern part of T. 17 N., then slopes more abruptly to Moreau River, which flows eastward near the middle of T. 16 N. A few small areas of sand dunes and badlands are scattered over the part south of the South Fork of Grand River, but most of the surface is grass-covered and used exclusively for stock raising. A few high buttes along the divide

north of the South Fork of Grand River are capped by resistant sandstone ledges and rise abruptly above the general level of the prairie.

Throughout nearly the entire area the surface rocks belong to the lower part of the Lance formation, the Ludlow lignitic member being represented in only a few elevated areas in Tps. 19 and 20 N. The soft sandy shale and friable sandstone weather easily to sandy soil, which obscures the bedrock except at a very few places. The strata dip gently to the northeast.

Lignite is exposed at only a few places in these townships, and from the general character of the rocks that underlie the area it is concluded that there are no beds of value except those whose outcrop is shown on Plate I (in pocket). Thin beds of lignite are exposed in the sides of two small buttes in secs. 4 and 10, T. 19 N. At location 235, in sec. 10, there is a bed 1 foot 6 inches thick; at location 236, in sec. 4, there are two beds, the upper, which is 1 foot 3 inches thick, about 40 feet above the lower, which is 1 foot thick.

A flat-topped butte in sec. 31, T. 20 N., is underlain by several feet of black shale, brown shale, and thin bands of lignite that is too poor to be used for fuel. At location 237, in sec. 21, a bed of lignite 1 foot thick is exposed at the base of the Ludlow lignitic member of the Lance. A thicker bed underlies a small area in secs. 1 and 2. At location 238 (see Pl. VII) the following section is exposed:

Section of lignite bed at location 238, in the NW. ¼ sec. 1, T. 20 N., R. 6 E.

	Ft.	in.
Shale.		
Lignite, dirty	1	6
Lignite		10
Sand		½
Lignite, dirty		5
Shale		3
Lignite		6
Shale.		
Total section	3	6½
Total lignite	3	3

This bed increases in thickness toward the east, and is 5 feet 6 inches thick at location 396, in sec. 6, T. 20 N., R. 7 E.

T. 21 N., R. 6 E.

There is a difference in elevation of about 500 feet between the top of the Cave Hills, in sec. 7, T. 21 N., R. 6 E., and the lowland along Jack Creek, about 2,900 feet above sea level, near the Van Horne ranch, in sec. 33. The low grassy divide between Big Nasty Creek on the north and Jack Creek on the south extends from the Cave Hills escarpment, in secs. 6 and 7, southeastward through the township. In the east-central portion the divide consists of a high,

flat mesa, due to a comparatively resistant sandstone that forms the cap. The valley of Big Nasty Creek, which traverses the north tier of sections from west to east, is broad, open, and grass-covered. The most conspicuous topographic feature is the North Cave Hills, which project into sec. 7, but lie for the most part to the northwest. These hills stand out prominently, because they are capped by a very massive sandstone some 100 feet in thickness, which resists erosion and forms a nearly vertical cliff around the margin of the mesa.

The Pelham ranch, in sec. 6, and the Van Horne ranch, in sec. 28, are well-known landmarks of this part of the field, and until recently constituted nearly the entire settlement. A few homesteaders have recently taken up tracts of land, but as a whole the township is better suited to grazing than farming.

Of the 500 feet of rock strata exposed, the lower 400 feet belongs to the Lance formation, which underlies the entire township except a small part of sec. 7. The lower 100 feet or so is composed of irregularly bedded sandy shale and sandstone, with a few beds of lignite. The upper 300 feet of the Lance formation carries the only valuable lignite beds, and is differentiated from the rest of the formation as the Ludlow lignitic member. It consists of sandy shale with a considerable amount of interbedded light-colored sandstone and lignite. The individual beds are more continuous than those of the lower part of the formation. The ridges in the east-central part of the township are capped by thin resistant sandstones, which protect the underlying soft shale and give rise to rugged topography.

The rim rock of the Cave Hills is a massive sandstone, about 100 feet thick, which is assigned to the Fort Union formation. It is light buff or yellow, in some places grayish, rather coarse grained, and loosely cemented. The upper part is somewhat more resistant than the lower and protects it from rapid disintegration. Ludlow Cave, in sec. 7, is a cavity in the massive sandstone, formed by the combined action of wind and water.

The strata are essentially horizontal and for most purposes may be so considered, the dip being too slight to be a serious factor in any mining operation. There is in sec. 8 an apparent local dip of about 3° SE., with a strike slightly north of east. In general the formations seem to have a very slight northeastward dip amounting to about 23 feet to the mile.

Two good lignite beds are exposed in this township. The lower is probably the same as the Widow Clark lignite of T. 21 N., R. 7 E., and its outcrop was traced in considerable detail and with a fair degree of accuracy. In the gullies leading down from the Cave Hills, in the northwest corner of the area (sections 253 to 258A, Pl. VI), the bed ranges in thickness from 1 foot 7 inches at location 255 to 3

feet 8 inches at location 254. To the east the bed thickens rapidly and at location 251, in sec. 15, it is 8 feet 8 inches thick. Along its outcrop, in the southeast quarter of the township, the thickness ranges from 3 feet 2 inches at location 242 to 6 feet 8 inches at location 248. At location 241b, in sec. 36, the bed is represented by 3 feet 10 inches of lignite, split by 5 feet of shale. Detailed sections measured along the bed are represented on Plate VI by Nos. 241b, 242, 243b, 245, 247b to 258, 258A, 261b, 262b, and 263. The lignite is not exposed along the south side of Big Nasty Creek because of the thick grass covering the slopes, but at one point in sec. 10 there is a slight burn which was considered to be on the bed. Strip mines have been operated at location 253, in sec. 8, and location 263, in sec. 24.

The upper valuable bed of lignite is separated from the lower by 20 to 40 feet of strata. It has burned at many places in the southeast corner of the township and also in sec. 12, giving rise to large masses of clinker. This bed is correlated with the Giannonatti bed in the township to the east, with the main bed around the northern extremity of the North Cave Hills, and with the T Cross bed at Ives, N. Dak. Sections of the bed at locations 239, 240, 241a, 243A, 244, 247a, 261a, 262a, 243a, 264, 265, 265A, 266, 267, and 268 (see Pl. VI) show that it ranges in thickness from 4 feet 1 inch at location 243a to about 12 feet 6 inches at location 239. Its cover reaches a maximum thickness of about 150 feet. The bed is correlated with the one containing 7 feet of lignite at the Pelham mine at location 268, in sec. 6. East of location 268 grass-covered areas conceal the outcrop of the bed, except at two localities in the SE. ¼ sec. 6 and the NE. ¼ sec. 7, where its presence is indicated by red burned rock.

A thin lignite bed outcrops at location 269, in the SW. ¼ sec. 1, and in detail is as follows:

Section of lignite bed at location 269, in the SW. ¼ sec. 1, T. 21 N., R. 6 E.

	Ft.	in.
Shale.		
Lignite		11
Shale		2
Lignite	1	1+
	2	2+

The entire thickness of this bed could not be measured because it was partly covered by water. Another unimportant lignite bed outcropping in the SW. ¼ SE. ¼ sec. 9 is, at location 259, 3 feet 2½ inches thick, with a thin shale parting near the middle. It does not continue as a thick bed for any great distance. Thin streaks of lignite at lower horizons are exposed in the creek bank in the SE. ¼ sec. 22. The following section was measured at location 246:

Section of lignite bed at location 246, in the SW. ¼ sec. 22, T. 21 N., R. 6 E.

	Ft.	in.
Shale.		
Lignite		9
Shale		3
Lignite		5
Shale		7
Lignite		10
Total section	2	10
Total lignite	2	0

Farther up the creek, in sec. 15, some thin beds occur but were not traced. At location 260, in sec. 25, there is 2 feet 8 inches of lignite, split by 3 inches of shale. No correlation of these isolated outcrops is attempted.

No samples for analysis were procured from any of the beds in this township, but the two principal beds are lignite of good quality. They have not been developed commercially to any extent, but there are three small strip pits where lignite has been obtained by the inhabitants for local use. Prospects on the lower bed have been opened in sec. 8 (location 253) and sec. 24 (location 263), and there is a small strip pit on the upper bed near Pelham's ranch at location 268, in sec. 6.

T. 22 N., R. 6 E.

A high, irregular ridge, with well-defined northward-facing slopes, extends from the Cave Hills, in secs. 30 and 31, T. 22 N., R. 6 E., to the Tepee Buttes, in sec. 6 of the township to the east, and separates the drainage of Crooked Creek on the north from that of Big Nasty Creek on the south.

A large part of T. 22 N., R. 6 E., is rolling and grass-covered, but badlands are developed locally and some conspicuous buttes stand out like monadnocks above the surrounding country. The butte in sec. 19 rises to an altitude of 3,777 feet above sea level. Three buttes in secs. 19 and 27 are capped by very hard quartzite which protects the underlying rocks from rapid erosion. Other buttes in secs. 16 and 31 are capped by the massive sandstone that forms the rim rock of the Cave Hills.

There are a few small springs in the township, and Crooked Creek contains running water throughout the greater part of the year. Water for domestic use is obtained chiefly from wells and is almost everywhere reached at rather shallow depths—20 to 30 feet. Nearly all the water is alkaline. A large part of the land has been taken up by homesteaders, but there are at present very few inhabitants. The little hamlet of Ludlow is located in the southwest corner of sec. 35.

A total thickness of about 600 feet of strata is exposed in this township. The lower part of the Lance formation, consisting of soft

dark-colored shale and sandstone with a single bed of lignite, is exposed along Crooked Creek, in the northern part. The rocks are decidedly cross-bedded and vary greatly in character, containing in places a great number of iron carbonate nodules which weather to dark-brown masses. The Ludlow lignitic member, which here includes all the upper part of the Lance, contains more yellow sandstone and sandy shale than the lower part and also includes all the valuable lignite beds. Where the sandstones are indurated they form gnarly outcrops, but elsewhere they weather to sandy slopes. The Fort Union formation, which is exposed in several high buttes, consists of about 235 feet of yellow and red sandstone similar to that on the Cave Hills, some shale, and a peculiar quartzite bed, bowlders from which are scattered abundantly over the surface.

The rocks in general dip eastward at about 30 feet to the mile, but in one or two localities minor folds have been developed. One of these occurs in the southwest corner of sec. 28 and seems to be a small anticline with its axis running nearly east. There is further evidence of the anticline in secs. 19 and 30, on the west side of the township.

The lowest bed of lignite occurs near the top of the lower part of the Lance formation and outcrops in the northern part of the township, in the valleys of the small tributaries of Crooked Creek. At location 290, in sec. 19 (see Pl. VI), the bed contains 6 feet 2 inches of lignite, but within a few rods it disappears beneath the creek, to reappear about a mile downstream. Sections 287, 288, and 289, exposed in secs. 7 and 18 (see Pl. VI), are supposed to represent the same bed and show an average thickness of more than 3 feet. At these places the bed is not so thick as the one exposed at the small mine near the Riley ranch, at location 211, in sec. 24 of the township to the west. Small strip mines have been opened at locations 288 and 289, in sec. 18.

Lignite beds in the Ludlow lignitic member of the Lance are exposed at a large number of places in the township, and at other places the outcrop of beds is indicated by baked rock that has resulted from the burning of lignite. Grassy slopes and rock slumps prevent the exact correlation of beds, but that indicated on the map (Pl. I, in pocket) seems to be the best. Beds at locations 272, 274, 275, 275A, 275B, 276, 277, 278, 285, 285A, and 286 are near the base of the member and range in thickness from 2 feet at location 285A to 8 feet 9 inches at location 274. Along the outcrop line joining these sections there are numerous areas of fused red rock, which are at the same horizon. The variation in thickness of this main bed is shown in detail on Plate VI.

In sec. 14 there are two beds above the main lignite. One, stratigraphically 70 feet higher (at location 284), contains 5 feet of lignite,

and 25 feet above this is a second bed more than 2½ feet thick that has been prospected at location 282. In a well at location 283, in the SE. ¼ sec. 14, 4 feet 6 inches of lignite was found at approximately the horizon of the middle bed. No lignite was found farther northeast in this township at either of these horizons. To the west, at location 281, in sec. 16, the middle bed is split by a shale parting into two benches and is nearly worthless. (See Pl. VI.) A bed in the southwestern part of the township, shown in sections 270, 271, 272, 279, and 280, lies about 20 feet above the main bed. At location 273 this bed is represented by 2 feet of lignitic shale.

Two beds of lignite 20 feet apart are exposed in a narrow valley in the southeast corner of the township. The lower, shown graphically by sections 298, 299, 300, and 301 (Pl. VI), reaches at location 299 a maximum thickness of 5 feet 6 inches; elsewhere, so far as ascertained, the bed is worthless. It is possible that the bed outcropping in sec. 33 and represented by section 291 is at the same horizon. The upper bed in this part of the township is exposed at locations 292, 293, 294, and 295, but it is not especially valuable. (See graphic sections, Pl. VI.) Lignite beds 3 feet and 5 feet thick at locations 296 and 297, respectively, are reported in wells and may correspond to the upper bed just described. The exact relation of the beds in the eastern part of the township to those exposed elsewhere is not known, but it is probable that the upper bed here is to be correlated with the bed represented by sections 279 and 280.

T. 23 N., R. 6 E.

The nortnern part of T. 23 N., R. 6 E., drains northward into the tributaries of the North Fork of Grand River, and the remainder into Crooked Creek, which meanders in a broad, open valley, and traverses the southern and eastern parts of the township from west to northeast. Through the middle of the area extends a low, rolling grassy divide. During the greater part of the year there is running water in Crooked Creek, but the other streams are intermittent. Nearly all the water for farm use is obtained from shallow wells, most of which yield alkaline water. In the NW. ¼ sec. 20 there is a small spring of good water. Although most of the tillable land has been homesteaded, the township has now only a few inhabitants.

The rocks exposed in this township belong to the Lance formation and are about 200 feet thick. They consist chiefly of dark shale interbedded with sandstone, one or two beds of lignite, and beds of carbonaceous shale. The upper portion of the exposed geologic section (the Ludlow lignitic member) contains a large amount of sandstone which weathers into irregular forms. The sandstone is somewhat lighter in color than the shale. being gray, yellow, and

buff. The rock strata dip eastward at about 15 or 20 feet to the mile, as determined by the altitudes of certain beds in this and adjacent townships.

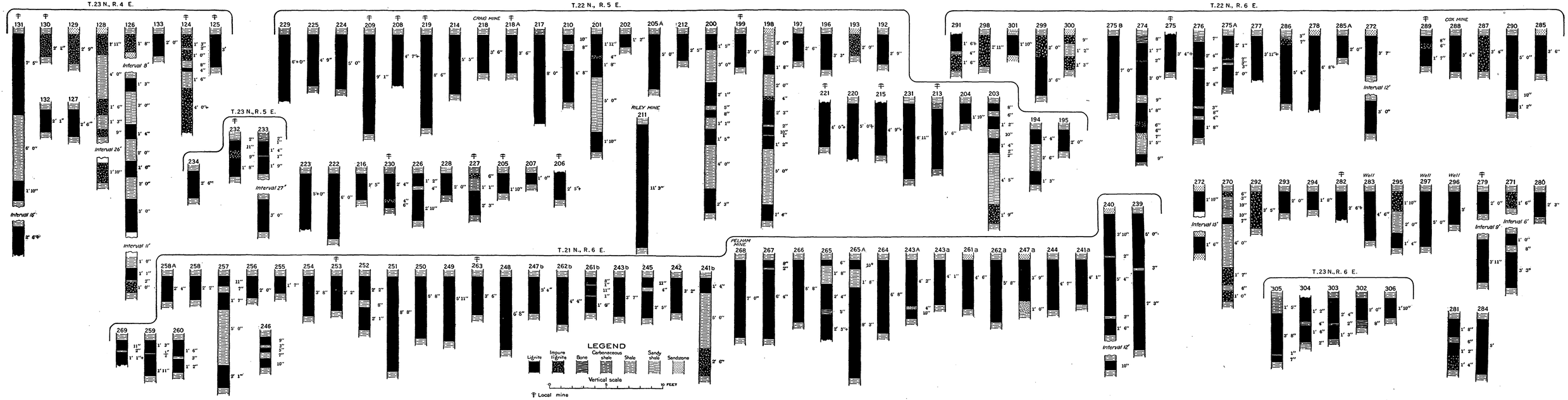
Only one bed of lignite of any value is exposed, and measurements of this bed were obtained at locations 302, 303, 304, and 305. (See Pl. VI.) The bed is the thickest at location 305 and thins to the south and east. East of location 304 the bed is not exposed, but near the northeast corner of sec. 21 considerable quantities of lignite have been dug up by prairie dogs. There is no evidence of the bed on the east slope of the divide in secs. 22 and 7, but at location 302, in the SW. ¼ sec. 27, 2 feet of poor lignite is exposed. At location 303, in the SE. ¼ NE. ¼ sec. 28, there is a section very similar to the one at location 304. It is said that in a well in the SW. ¼ sec. 28 a few inches of lignite was found. Another well, on the south side of sec. 20, encountered lignite at a depth of 22 feet. There is 1 foot 10 inches of poor lignite exposed at location 306, on the north side of sec. 29, which may be at the same horizon.

T. 16 N., R. 7 E.

T. 16 N., R. 17 E., is drained entirely by the North Fork of Moreau River, which flows eastward across the southwestern part. The surface of the township is rolling and grass covered, except in the northeast corner, where the Slim Buttes rise more than 600 feet above the general level of the country. The top of the mesa is level and grass covered and is surrounded by a nearly vertical sandstone cliff. Below this cliff is a zone of deeply cut badlands, in which, except at a few places, slumps effectually conceal the character of the strata on the lower slopes.

The sandstone cap of the Slim Buttes belongs to the Arikaree (?) sandstone, and below it are clay and sandstone of the White River formation. At the south end of the Slim Buttes, in this township, the White River formation rests on the lower part of the Lance formation, but to the north the basal portion of the Ludlow lignitic member of the Lance is exposed. The strata dip northeastward, and the increase in thickness of the Ludlow lignitic member toward the north is due to this northeasterly dip, rather than to inequality of the erosion surface upon which the White River formation was deposited.

Lignite in the lower part of the Lance formation is exposed at three localities in secs. 12 and 13. At location 307, in sec. 13, there is 1 foot 10 inches of very dirty lignite; at location 308 a bed containing 2 feet 2 inches of dirty lignite is exposed; and at location 309 there is 2 feet 5 inches of dirty lignite at a horizon several feet below that of the bed exposed at location 308.



LIGNITE SECTIONS IN HARDING COUNTY, S. DAK.

In area examined by C. J. Hares.

Because of the large amount of slumping which has taken place around the Slim Buttes, lignite beds can be seen in only a few places and such beds as are exposed can not be correlated with certainty. Less than 50 feet above the base of the Ludlow lignitic member of the Lance is a thick mass of brown and black shale with several thin beds of lignite (location 312). The highest bed has burned, leaving only a bed of red baked clay, so that the original thickness of the bed can only be estimated.

Sections of the Ludlow lignitic member in secs. 1 and 2, T. 16 N., R. 7 E.

Location 312.

	Ft.	in.
Clay.		
Lignite, burned; thickness unknown.		
Clay	5	0
Lignite		3
Clay	1	4
Sandstone	7	0
Shale, brown	1	0
Shale, black, carbonaceous		3
Lignite		9
Shale, brown		1
Lignite		9
Bone		2
Clay	8	0
Lignite, dirty	2	2
Shale, black, carbonaceous		1
Lignite		5
Clay		10
Bone		5
Clay	1	5
Lignite	1	6
Shale, brown		6
Lignite		3
Shale, black, carbonaceous		2
Lignite		11
Shale, brown		10
Lignite		4
Clay.		
Total section	34	5
Total lignite	7	4

Location 310.

	Ft.	in.
Shale.		
Lignite, dirty	2	11
Bone		3
Shale, brown and black, partly carbonaceous	22	0
Lignite, dirty	1	10
Shale, brown to black, partly carbonaceous	2	8
Clay.		
Total section	29	8
Total lignite	4	9

Location 311.

Clay.		
Lignite	2	3
Clay.		

T. 17 N., R. 7 E.

Along the east side of T. 17 N., R. 7 E., the Slim Buttes mesa rises in an almost vertical cliff to an altitude nearly 600 feet above that of the surrounding plain. The top of the mesa is gently rolling, and upon it there is a heavy growth of grass and a few pine trees; the trees are most abundant about the margin. Around the mesa is an area of slumped rocks which recent erosion has dissected at a

number of places into nearly impassable badlands. The surface of the western two-thirds of the township is gently undulating, having numerous small valleys through which the run-off from the area finds its way to the South Fork of Grand River on the north and to Moreau River on the south. The soil, which in a large part of the township is the result of the disintegration of the sandy shale and soft sandstone of the lower part of the Lance formation, is of fair quality and is being cultivated by a number of farmers. Numerous springs issue from a sandstone near the base of the Slim Buttes and furnish excellent water in sufficient quantity to be used for irrigating small patches of land in the plains area to the west.

All the main stream valleys are cut into the lower part of the Lance formation, but the Ludlow lignitic member caps a few of the higher divides and outcrops in a narrow belt along the slope of the mesa. The White River formation, resting unconformably upon the Ludlow lignitic member of the Lance, is composed of flesh-colored and yellow clay and white sandstone, locally conglomeratic. Numerous fossil bones found in these rocks prove the formation to be of Oligocene age. Above the White River, and possibly unconformable to it, is a heavy-bedded, almost homogeneous sandstone which is assigned to the Arikaree (?) sandstone. No fossils have yet been found in this sandstone, and its age is determined solely on lithologic character. The strata dip gently in a direction slightly north of east.

All the lignite in this township is in the Ludlow lignitic member of the Lance. The individual beds are probably not continuous over large areas, but where one pinches out another or several others may appear in the section, so that wherever the strata are well exposed one or more beds may be seen. Although there is sufficient lignite exposed at several localities to warrant mining, the demand for fuel is not great and only two small strip mines have been opened. At the Red Butte mine (location 315; see Pl. VII), in sec. 35, lignite is mined from the upper bed, and at the Mendenhall mine (locations 325 and 326), in sec. 1, the middle and lower beds are worked. Analyses 13222 and 13220 (p. 42) show the quality of the lignite in the two beds, respectively. The beds were measured at a number of places along the west face of the Slim Buttes. and the following table shows their thickness and correlation·

Sections of lignite beds in T. 17 N., R. 7 E.

No. on Pl. I.	Location.	Bed.	Section.	Ft.	in.
313	SE. ¼ sec. 35	Middle and lower	Clay.		
			Lignite, dirty	1	9
			Shale, brown	2	1
			Lignite		6
			Shale, black to brown	1	7
			Lignite		3
			Shale, brown		1
			Lignite		3
			Shale.		
			Total section	6	6
			Total lignite	2	9
314	do	Highest	See Plate VII.		
315	NE. ¼ sec. 35	do	Do.		
316	SW. ¼ sec. 26	Middle and lower	Shale, brown, with thin bands of lignite	10	0
317	NW. ¼ sec. 26	Upper	Sandstone.		
			Shale, carbonaceous		3
			Lignite, dirty	4	8
			Shale.		
			Interval	12	
		Middle	Lignite, dirty	2	8
			Total section	19	7
			Total lignite	7	4
			Lignite, dirty	2	0
318	do	Lower	See Plate VII.		
319	do	Upper	Do.		
320	SE. ¼ sec. 23	do	Do.		
321	NE. ¼ sec. 23	do	Do.		
322	SW. ¼ sec. 13	do	Lignite, dirty	2	4
323	NW. ¼ sec. 12	do	Lignite, dirty	2	6
324	do	do	Interval	10	0
			Lignite	1	0
		Middle	Total section	13	6
			Total lignite	3	6
325	SW. ¼ sec. 1	Middle and lower	See Plate VII.		
326	SE. ¼ sec. 1	Upper	Do.		
327	Sec. 2	Uncorrelated	Lignite, dirty	2	6

T. 18 N., R. 7 E.

Several streams flowing in wide valleys converge toward the northwest corner of T. 18 N., R. 7 E., where they join to form Squaw Creek. Sioux Creek, one of the largest, heads in Reva Gap, in the Slim Buttes. Between the streams are fairly high divides capped by rocky points. The northeast and southeast corners of the township are occupied by parts of the high Slim Buttes mesa, which stands about 600 feet above the general level of the plains. Numerous good springs issue from rocks along the edge of the mesa, and several large stock ranches have been so located as to take advantage of the excellent water. Only a small part of the area is cultivated.

The lower part of the Lance formation outcrops in the stream valleys, and the Ludlow lignitic member caps the divides and outcrops around the Slim Buttes. The Ludlow in turn is overlain unconformably by clay and conglomeratic sandstone of the White River formation. The highest formation exposed, making the cliff of the buttes, is a fine-grained whitish sandstone which is supposed to belong to the Arikaree (?) sandstone. The lignite-bearing strata dip gently to the northeast.

The more valuable beds of lignite outcrop around the borders of the Slim Buttes in the Ludlow lignitic member of the Lance. These beds vary considerably in thickness from point to point, as do also the distances between them. The section at location 333 (see Pl. VII), in the SW. ¼ sec. 24, probably includes all the beds and may be considered typical for the southwestern part of the township. It comprises three beds of lignite more than 4 feet thick and two thinner beds. Eastward from that place the strata are concealed for about a mile, and where they are exposed again at location 334, in sec. 24, each of the beds is only 2 feet or less in thickness. The section is as follows:

Section of lignite beds at location 334, in the SE. ¼ sec. 24, T. 18 N., R. 7 E.

	Ft.	in.
Clay.		
Lignite	1	11
Clay	9	0
Lignite	1	0
Shale, brown, sandy, carbonaceous	15	0
Lignite, somewhat dirty	2	0
Shale.		
Total section	28	11
Total lignite	4	11

South of location 333 both the lower beds of that section are exposed at location 322 and the lowest bed at locations 330 and 328. At location 328 the bed is 13 feet 8 inches thick and is the thickest bed in this part of the field. The bed is separated into two benches by 1 inch of shale, which presumably thickens toward the south, so that the single bed at location 328 represents the two lower beds at locations 325 and 326, in the township south of this one. The middle bed of section 333 is exposed at location 331 and is probably represented by the two beds at location 329. These beds are 7 feet 10 inches and 3 feet 11 inches thick, and are separated by only 3 feet 1 inch of shale and sandstone. The detailed sections at all these points are shown in Plate VII.

North of Sioux Creek, on the east side of sec. 1, four beds of lignite are exposed within a stratigraphic distance of about 100 feet. The highest is nearly 12 feet thick and is represented on Plate VII by

section 335. Ten feet below is a bed which is 2 feet 6 inches thick (location 336), and 45 feet below is a third bed of dirty lignite (location 337), 2 feet 4 inches thick. The bed exposed at location 338 is the lowest in the section and contains 2 feet 6 inches of excellent lignite. In another gully, less than half a mile farther west, the two upper beds are absent and the base of the White River formation is considerably lower. This seems to indicate that erosion had produced a rather irregular surface in this vicinity before the White River sediments were deposited. The two lower beds are poorly exposed, but both appear at location 339, in the SW. ¼ sec. 1, where the upper of the two is 2 feet thick and the lower 1 foot 9 inches thick and of good quality. Half a mile farther west, at location 340, each bed is less than a foot thick. Northwestward beyond this point the beds could not be followed and are presumably absent.

Below the beds described is a lens 2 feet 2 inches thick, occurring in sec. 5 at location 341, at the base of the Ludlow lignitic member of the Lance formation. At about 50 feet below this bed, in the lower part of the Lance, the following section is exposed:

Section of lignite beds at location 342, in the SE. ¼ sec. 4, T. 18 N., R. 7 E.

	Ft.	in.
Shale.		
Lignite	2	3
Shale, brown	4	7
Lignite, dirty	3	0+
Total section	9	10+
Total lignite	5	3+

The bottom of the bed was covered by water, preventing complete measurement. This bed is not present along the valley to the south of Sioux Creek and is covered by wash north of location 342, but it is probably the same bed as the one exposed at location 343, in the township to the north.

T. 19 N., R. 7 E.

The South Fork of Grand River crosses the northwestern part of T. 19 N., R. 7 E., in a wide sandy valley and receives the drainage of the whole area north of the Slim Buttes. These buttes, which rise about 600 feet above the general level of the surrounding country, occupy the southeastern part of the township. North and west of the buttes the surface is deeply dissected into intricate badlands. Numerous prominent ridges and buttes are capped by the resistant red clinker caused by the burning of lignite beds and form striking features of the area. Slumps are especially common about the edge of the mesa, in many places obscuring the lignite beds. Numerous springs occur at the base of the Slim Buttes, but the rugged nature of the surface in their vicinity has prevented the

establishment of ranches or farms that could take advantage of the water. Only a very small part of the township is suitable for cultivation.

The main valleys are cut into the lower part of the Lance formation, and the Ludlow lignitic member outcrops along the divides and in a narrow belt about the foot of the buttes. The Ludlow is overlain unconformably by the non lignite-bearing conglomeratic sandstone and clay of the White River formation, and these in turn by the fine-grained Arikaree (?) sandstone.

The lignite-bearing beds dip gently to the northeast. Several beds of lignite, all of rather poor quality and of slight extent, crop out in the township. The lowest bed is near the top of the lower part of the Lance formation and is thought to be the same bed as the one on which section 342 was measured, in T. 18 N., R. 7 E. At location 343, in sec. 33 of this township, it is thicker than to the south, but poor in quality. (See Pl. VII.) To the north the bed thins and is not exposed in the valley in secs. 27 and 28, but at locations 344, 345, and 346 sections were obtained, and the lens at location 347, in sec. 22, is supposed to represent the same bed.

Sections of beds along lowest lignite horizon in T. 19 N., R. 7 E.

Location 344. NE. ¼ sec. 29.

	Ft.	in.
Shale.		
Lignite	1	3
Shale, brown	1	6
Lignite	1	11
Shale.		
Total section	4	8
Total lignite	3	2

Location 345. SW. ¼ sec. 20.

	Ft.	in.
Shale, brown.		
Lignite		10
Shale, carbonaceous	2	0
Clay	10	0
Shale, brown	1	0
Lignite		10
Shale.		
Total section	14	8
Total lignite	1	8

Location 346. NE. ¼ sec. 21.

	Ft.	in.
Shale, brown.		
Lignite	1	4
Shale, brown		6
Lignite		5
Shale.		
Total section	2	3
Total lignite	1	9

Location 347. NE. ¼ sec. 22.

	Ft.	in.
Clay.		
Lignite, dirty		9
Clay, gray, with thin bands of lignite	4	6
Lignite	1	4
Lignite, very dirty		9
Clay.		
Total section	7	4
Total lignite	2	10

A bed of lignite at the base of the Ludlow lignitic member of the Lance is exposed at three places. At location 352, in sec. 15, it is represented by a thick bed of shale with 10 inches of lignite; at location 353, in sec. 23, it is represented by 1 foot 6 inches of lignite, with a 3-inch shale parting 6 inches from the top. A more extensive lens has considerable lignite at locations 355 and 356, in sec. 12 (see Pl. VII), and at location 354, in sec. 13, there is 2 feet 3 inches of lignite with a 2-inch shale parting in the middle.

Several isolated outcrops, probably representing small lenses of lignite, occur higher in the Ludlow member. Three of these are exposed in a gully in the south side of sec. 26; the lowest, at location 360, is 1 foot 1 inch thick; the next, at location 359, contains 1 foot 7 inches of poor lignite; and the upper, at location 358, contains 2 feet 1 inch of good lignite. At location 365, in the northwest corner of sec. 24, the following measurement of a lignite bed near the base of the Ludlow member was made:

Section of lignite bed at location 365, in sec. 24, T. 19 N., R. 7 E.

	Ft.	in.
Clay, gray.		
Lignite		5
Clay	2	0
Lignite, dirty		4
Lignite	1	0
Lignite, dirty		9
Clay.		
Total section	4	6
Total lignite	2	6

At location 357, in the southwest corner of sec. 14, there is a bed 1 foot 6 inches thick, probably the same as that underlying the ridge in the center of the township, along which sections 348, 349, 350, and 351 were measured. The cover above the bed at these four locations is not great, so it is probable that the lignite has deteriorated considerably through oxidation and is of little value. In a small strip pit at location 351, in sec. 9, there are two beds containing 4 feet 4 inches and 3 feet 4 inches of lignite, separated by 2 feet 3 inches of shale. (See Pl. VII.) To the south this bed thins to 3 feet 4 inches at location 350 and is less valuable at locations 348 and 349, as is shown by the following sections:

Section of lignite beds in the SE. ¼ sec. 16, T. 19 N., R. 7 E.

Location 348.

	Ft.	in.
Shale.		
Lignite		7
Shale, brown		1
Lignite	1	0
Shale, brown		2
Lignite		9
Shale, brown		1
Lignite		8
Shale.		
Total section	3	4
Total lignite	3	0

Location 349.

	Ft.	in.
Shale, brown.		
Lignite		3
Shale, brown	2	11
Lignite, dirty	2	7
Bone		3
Lignite		4
Clay.		
Total section	6	4
Total lignite	3	2

At the foot of the Slim Buttes is the outcrop of a thick series of brown and black shale, with several beds of lignite. This series will be considered as a whole, because the correlation of separate beds is rendered uncertain, not only by the varying character of the beds

themselves but also by the slumping. No lignite is present in the series in sec. 35, but at location 361, in sec. 26, two beds 2 feet 4 inches and 2 feet 1 inch thick are exposed, separated by 2 feet 6 inches of shale. Both beds thicken to the north and the distance between them is less, as shown by sections 362 and 363, Plate VII. At 15 feet below section 363 there is another bed (section 364), containing 3 feet 7 inches of lignite, separated into two benches by 4 inches of shale. At location 366, in the NE. ¼ sec. 23, near the top of a small butte, the lignite is so much weathered that the quality is uncertain, but the bed is at least 4 feet thick. At location 367 (see Pl. VII) several thin beds of lignite interbedded with shale represent the horizon. At location 368, in sec. 24, the following section is exposed in a bed 25 feet below the one just described:

Section of lignite bed at location 368, in the NE. ¼ sec. 24, T. 19 N., R. 7 E.

	Ft.	in.
Shale.		
Lignite, dirty		11
Shale, brown	1	2
Lignite	2	0
Shale.		
Total section	4	1
Total lignite	2	11

Slumping of the younger rocks has been especially common along the north side of the Slim Buttes, and here and there the lignite beds themselves are out of place, so that in sec. 24 the correlation of the different measured sections is uncertain. Sections 369 and 370 (Pl. VII) are supposed to represent the same bed as section 367, and the following section (No. 371) is on the same bed as section 368.

Section of lignite bed at location 371, in the NE. ¼ sec. 24, T. 19 N., R. 7 E.

	Ft.	in.
Shale.		
Lignite, dirty		6
Lignite	1	2
Shale, brown	1	0
Lignite	2	0
Shale.		
Total section	4	8
Total lignite	3	8

A bed of lignite 2 feet 5 inches thick, with a 2-inch shale parting near the top, outcrops high on the side of the mesa, but just below the White River formation, at location 372, in the SE. ¼ sec. 24. This is probably the same bed as that showing at location 335, in T. 18 N., R. 7 E., but the bed does not outcrop elsewhere in T. 19 N., R. 7 E.

T. 20 N., R. 7 E.

The southern part of T. 20 N., R. 7 E., lies in the broad, slightly rolling sandy valley of the South Fork of Grand River. Along the

south side of the river there is a well-defined terrace about 35 feet above water level. North of the river the surface rises gradually to rocky divides capped by level-topped buttes that occupy considerable areas. The high lands are drained by Horse and Coal creeks, which flow southeastward in broad, open valleys.

The Lance is the only formation outcropping in this township. The Ludlow lignitic member of the Lance underlies the divides and the higher land to the north. In general the rocks show a very slight northeasterly dip, but there seems to be a gentle anticline trending north in the northeastern part of the township, which gives in sec. 22 a distinct local northwest dip of more than 3°. Elsewhere the dip does not exceed 100 feet to the mile.

Several beds of lignite, all lenticular, are exposed in this township, but many of them, being but a few inches thick, are not represented on the map. As in many other townships in this field, there is a bed of lignite about 40 feet below the base of the Ludlow lignitic member. It was examined at several places but was mapped only at location 373, in sec. 20, where there is 1 foot of lignite and several feet of brown shale. At the base of the Ludlow member lenses are present at a number of places, but only the two more valuable ones are shown on the map. The one at location 374, in sec. 17, has a total of 2 feet 10 inches of dirty lignite, with a 2-inch sandy parting near the bottom. In sec. 23 the bed was traced for a mile; at location 375 it is 1 foot 4 inches thick, and at location 376, 1 foot 8 inches thick.

At least five beds of lignite crop out in the area occupied by the Ludlow lignitic member. The relation and correlation of these beds are shown in the following table:

Relation and correlation of lignite beds in the Ludlow lignitic member of the Lance formation in T. 20 N., R. 7 E.

	Feet.
Lignite bed shown in sections 401 and 387, Plate VII, and 389, page 93.	
Interval	10
Lignite bed shown in sections 388 and 390, page 92.	
Interval	40–60
Lignite bed shown in sections 377, 378, 382, 383, 384, 385, 396, 397, 398, and 399, Plate VII, and 381, page 92.	
Interval not known.	
Lignite bed shown in section 391, page 92.	
Interval not known.	
Lignite bed shown in sections 392 and 393, page 92.	
Uncorrelated:	
Section 436, Plate VII.	
Sections 379 and 380, page 93.	
Section 394, page 93.	

Of these beds the highest shows the thickest section (sec. 401, Pl. VII), but the bed underlies only small areas in secs. 4 and 5, and is therefore commercially unimportant.

Ten feet below this thick bed is one which is exposed at only two places. At location 388, in sec. 5, there is less than a foot of lignite and at location 390, in sec. 4, the bed is 2 feet 1 inch thick.

The third bed, 40 to 60 feet lower, underlies a considerable area and is the only one of value in this township. As shown by the sections on Plate VII, the bed ranges in thickness from 2 feet 2 inches at location 377, in sec. 22, to 6 feet 4 inches at location 399, in sec. 5. At location 381, in sec. 3, the bed is only 2 feet thick. Sections 377, 378, 396, 397, and 398 were measured in isolated hills where the bed underlies only small areas.

A lower bed at location 391, in the SE. ¼ sec. 4, shows the following section:

Section of lignite bed at location 391, in the SE. ¼ sec. 4, T. 20 N., R. 7 E.

	Ft.	in.
Shale.		
Lignite		7
Shale, brown	1	2
Lignite		10
Lignite, dirty		3
Shale.		
Total section	2	10
Total lignite	1	8

The lowest bed is exposed at locations 392 and 393, where the following sections were measured:

Sections of lignite in secs. 4 and 5, in T. 20 N., R. 7 E.

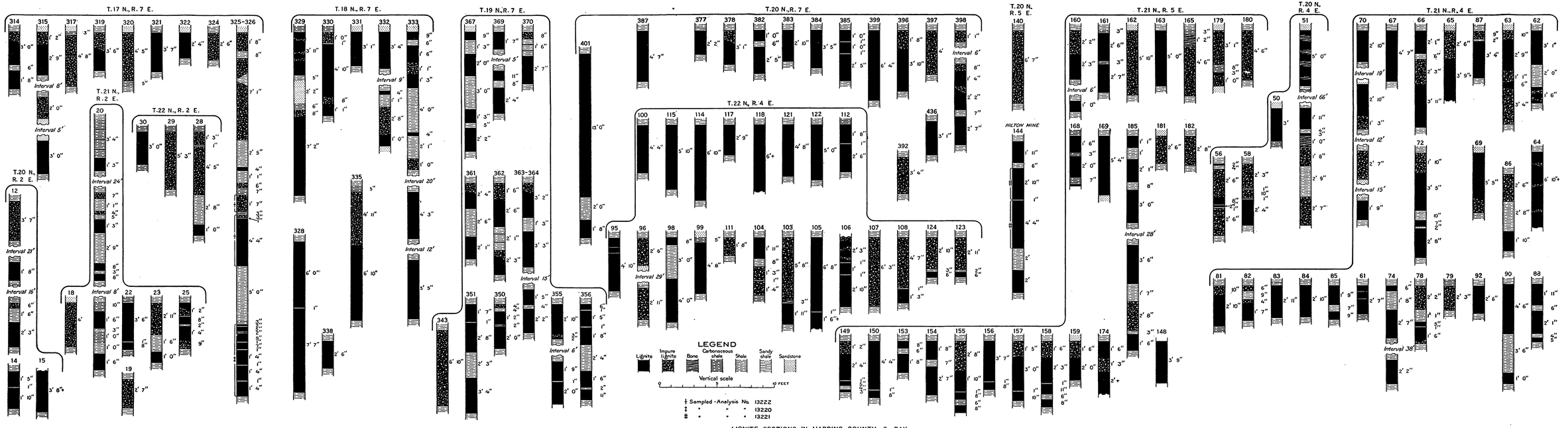
Location 392. Sec. 5.

	Ft.	in.
Shale.		
Lignite, dirty		8
Shale, brown	13	0
Lignite	3	4
Shale.		
Total section	17	0
Total lignite	4	0

Location 393. Sec. 4.

	Ft.	in.
Shale.		
Lignite, dirty	1	1
Clay		1½
Lignite	1	3
Shale.		
Total section	2	5½
Total lignite	2	4

The following sections of beds exposed at four other locations could not be correlated with the beds already described and are therefore treated as isolated exposures and may represent only local lenses:



LIGNITE SECTIONS IN HARDING COUNTY, S. DAK.

In area examined by E. M. Parks.

Sections of uncorrelated lignite beds in T. 20 N., R. 7 E.

Location 379. SE. ¼ sec. 1.

	Ft.	in.
Lignite	2	0

Location 380. NE. ¼ sec. 1.

	Ft.	in.
Shale, brown.		
Lignite		8
Shale		1
Lignite	1	0
Shale	34	0
Lignite		5
Shale		2
Lignite, dirty		6
Shale		2
Lignite, dirty		10
Shale.		
Total section	37	10
Total lignite	3	5

Location 394. Sec. 3.

	Ft.	in.
Lignite, poor		10
Lignite	1	2

Location 436. NE. ¼ sec. 1.

	Ft.	in.
Shale.		
Lignite	3	1
Shale.		

Location 389. NW. ¼ sec. 4.

	Ft.	in.
Shale, brown.		
Lignite, dirty	2	3
Shale, brown	1	6
Lignite		10
Shale.		
Total section	4	7
Total lignite	3	1

T. 21 N., R. 7 E.

The high divide extending southeastward across T. 21 N., R. 7 E., from sec. 19 separates the drainage of Big Nasty Creek from that of the South Fork of Grand River and has an average altitude of about 3,200 feet above sea level. South of the divide the land is deeply dissected into badlands, with many bare slopes and sharp valleys. To the north the country is less broken and is grass-covered. Much of the region is rugged, and level tracts of tillable land are scarce. There are, however, small areas of fairly level land in the east-central part which have been farmed. Springs are numerous in the area and furnish good water for stock; none of the land, however, is so situated that it could be irrigated, except possibly a few small areas along the valley of Big Nasty Creek. Nearly all the middle and northern portions of the township have been filed upon by homesteaders, but the southern two tiers of sections are comparatively unoccupied.

The lowest rocks outcropping in this township are exposed in the valley of Horse Creek, in sec. 34, where the dark argillaceous shale of the lower part of the Lance formation occupies a small area. The greater part of the lower 350 feet of the geologic section is assigned to the Ludlow lignitic member of the Lance formation and consists of sandy and carbonaceous shale, calcareous sandstone, and lignite interbedded. The upper 50 or 100 feet of rocks are assigned to the Fort Union formation. They are very fine grained, sandy, and of light color. Small areas of alluvium occur along the valley of Big Nasty Creek but were not mapped. The strata have a northeastward dip of 15 to 25 feet to the mile. In the southeast corner of the township, in secs. 25 and 26, there seem to be local folds which cause the strata to dip to the northwest.

There is an abundance of lignite in this township. Two important beds and several unimportant beds were mapped. The thinner beds are the lowest and the thicker beds the highest in the geologic section.

The Giannonatti bed is the highest and thickest, having a maximum thickness of 13 feet 6 inches at location 414 (see Pl. VIII), in the northeast corner of sec. 29, and an average thickness in this township of more than 8 feet. Three strip pits have been opened on this bed at locations 415, 416, and 417 near the head of Horse Creek, but the total thickness of the bed is not exposed at any of these places, so that the bed may be much thicker than is shown by the sections. The bed is exposed at locations 406 to 421, 423 to 425, and 435. The bed outcrops along the divide in the southern part of the township and is supposed to be the same as the main lignite bed around the North Cave Hills and the T Cross bed at Ives, N. Dak. The lignite of this bed is good, containing a very little shale and a small amount of marcasite as impurity. All the sections measured on this bed are shown graphically in Plate VIII.

In the vicinity of Two Tops Buttes, in the southeast corner of the township, there is a thin bed of lignite 3 feet 3 inches to 4 feet in thickness (sections 434, 435, and 438, Pl. VIII), 11 feet below the Giannonatti bed.

The Widow Clark lignite bed, so called because it is well exposed (9 feet 6 inches) in the neighborhood of the Clark ranch, at location 442, in sec. 14, is 50 to 70 feet below the Giannonatti bed. Sections 402, 404, 405, 427 to 429, 431 to 433, 437, and 439 to 450 (see Pl. VIII), which are supposed to represent the bed, show a considerable variation in thickness as well as quality of lignite. At location 444, on the east side of sec. 24, the bed is 2 feet 11 inches thick, but at other places along the outcrop in the same valley it shows a much greater thickness. (See sections 440 to 443, Pl. VIII.) A bed at location 437, in the southern part of sec. 36, doubtfully correlated with it, is 3 feet thick. If this is not the same bed, then the Widow Clark lignite is of little value in sec. 36. In the southwest corner of the township measurements on what is supposed to be the Widow Clark lignite range from 3 feet to 8 feet 2 inches (locations 402, 404, 405, 427, 428, 429, 431, 431A, 432, and 433). At locations 446 to 450, on the south side of Big Nasty Creek, there is a lignite bed which is correlated with the Widow Clark bed. At locations 446, 447, and 448, in secs. 3 and 9, it is about 2 feet 10 inches thick, but at location 449, in sec. 8, it is of little value. At location 450, in sec. 6, a carbonaceous zone, which was considered to be at the same horizon, is exposed, but the thickest bed of lignite is only 1 foot 6 inches thick.

The Bond bed outcrops in sec. 4 and contains 2 feet 1 inch of lignite at location 451 and 3 feet 8 inches of lignite, separated into two parts by 10 inches of carbonaceous shale, at location 452.

Along the stream valley in sec. 33 a thin bed of lignite about 3 feet thick is exposed at locations 453 and 454. This bed may be the same as that seen at location 426, in sec. 31, and the lower lignite bed exposed at locations 409 and 405.

A bed of lignite lying between the Widow Clark and Giannonatti bed outcrops at locations 409, 410, 403, and 430, in secs. 31, 32, and 33. It ranges in thickness from 3 feet to 4 feet 2 inches. At location 422, in sec. 8, a bed of lignite above the Giannonatti bed shows 2 feet 2 inches of lignite separated by 3 feet 3 inches of shale from a higher bed of lignite 3 feet thick.

T. 22 N., R. 7 E.

The Tepee Buttes, the most prominent topographic feature in T. 22 N., R. 7 E., consist of several high, pointed hills in secs. 5, 6, 7, and 8. A great number of bowlders from the quartzitic bed of the Fort Union formation cover these hills. The highest point in the township is located in the middle of sec. 7 and has an altitude of 3,266 feet above sea level. Eastward from the Tepee Buttes a rather high, flat divide, with an altitude of about 3,000 feet above sea level, extends across the area and joins the high table-land in T. 22 N., R. 8 E. From this divide the surface slopes southeastward to Big Nasty Creek and northward to the North Fork of Grand River. Away from the Tepee Buttes the surface is roughly rolling and grass-covered, and on the south side of the divide there are several steep hills, capped by rugged ledges of sandstone. The uplands are completely dissected and well drained, and the relief is virtually at a maximum. The larger streams meander widely over the lower portions of their valleys. Big Nasty Creek contains water at nearly all seasons of the year, and always has numerous large pools of water along its course. Its larger tributaries, Williams Creek and Lemmon Creek, are intermittent and flow in a general southeasterly direction.

Nearly the whole of the township has been taken up in homesteads, and many attempts have been made to raise flax, wheat, and corn, but with only partial success. It is probable that the land is better adapted to stock raising than to farming.

As the surface is almost completely grass-covered or cultivated, exposures of rock are very few, consequently a detailed study of the rock formations in this township is very difficult. All the rocks exposed, except those along the divide in the northern part of the township, are assigned to the Ludlow lignitic member of the Lance formation, which consists principally of soft yellowish sandstone, with beds of light-colored sandy shale and lignite. In places the rocks of the Ludlow member show a marked resemblance to those of the overlying Fort Union formation, and the line between the two is therefore an indefinite one. All the lignite beds outcropping in this part of the field belong to the Ludlow. The Fort Union forma-

tion is confined to the northern part of the township, and occupies only the higher areas. It is composed principally of yellow sandstone, but contains some shale, and its total thickness possibly does not exceed 100 feet. A narrow strip of alluvium borders Big Nasty Creek as a thin coating a few feet thick. The beds have a northeasterly dip of less than 25 feet to the mile, as determined by elevations along lignite outcrops. Local minor variations occur in this structure.

Several thin beds of lignite outcrop in the township. The correlation of outcrops on the south and north sides of the divide, in the middle of the township, is nearly impossible, because of the grass-covered surface which conceals nearly all key rocks. In the southern part of the township the Bond bed is the lowest of value. It attains its maximum thickness (see Pl. VIII) at the small mine in sec. 28 (location 457), where there is reported to be more than 7 feet of lignite, though at the time of examination only 3 feet was exposed above water. The bed is 4 feet thick at location 455, in sec. 32, and also at the mine on the Bond ranch (location 456). Sections 455 to 458 and 460, Plate VIII, represent the Bond bed. It ranges in thickness from 1 foot 9 inches at location 462 to more than 7 feet at location 457. At locations 459, 461, and 463, which are assumed to be on the same bed, the thicknesses are 1 foot 3 inches, 1 foot 4 inches, and 1 foot 4 inches, respectively.

At 20 feet below the Bond bed there is a bed showing in a spring at the Bond ranch a thickness of 1 foot 1 inch. About 60 feet above the Bond bed is another exposed at locations 464 to 467. In a small mine at location 465, near the west side of sec. 21, there is 3 feet 8 inches of lignite. At location 466 this bed contains 2 feet 8 inches of dirty lignite, but at locations 467 and 464 the lignite is replaced by carbonaceous shale. Above the bed just described, in the NW. ¼ SW. ¼ sec. 30 and in the NW. ¼ sec. 20, there are two small areas of clinker which are supposed to be on the same bed as that reported to be 3 feet thick in the well in the NW. ¼ sec. 18.

North of the Tepee Buttes there are three beds of minor importance. The bed exposed at locations 468, 470, and 469 is the upper one, its elevation being about 2,950 feet above sea level. It ranges in thickness from 1 foot 3 inches at location 468 to 2 feet at location 469. About 30 feet below this is a bed which at location 471, in sec. 6, is 1 foot 4 inches thick, and in the small mine at location 472 is 1 foot 6 inches thick. The third and lowest bed, which is correlated on the basis of its altitude with the lowest bed in the township to the west, is exposed at location 473, where it is 1 foot 3 inches thick.

T. 23 N., R. 7 E.

The drainage from T. 23 N., R. 7 E., goes into the North Fork of Grand River through small tributaries which flow in a general

northward direction. There are no springs of importance in the township, and the inhabitants are forced to rely on wells as a source of water. The total relief is about 225 feet, one of the highest points being on the State line in sec. 21, where the elevation is 3,010 feet above sea level. Considered as a whole, the township has a rather uneven, rolling surface, with a great number of grassy slopes. The western side of the township is low, but in the middle there is a fairly high, flat upland which is a continuation of the larger plateau-like area to the southeast and is due partly to a cap of somewhat resistant sandstone and thin limestone. In the southwest corner a great number of quartzite bowlders are scattered over the surface and, in a small measure, protect it from erosion and greatly interfere with cultivation. These bowlders originate from a quartzitic bed in the Fort Union formation.

The township has been fairly well settled by homesteaders, who have attempted to grow flax, wheat, and corn, but with only partial success, and it is probable that the region is not suitable for dry farming.

The lower 200 feet of rocks are considered to belong to the Lance formation. In the western portion of the township the lower part of the formation consists chiefly of dark-colored sandy shale, interbedded with a few thin carbonaceous layers and beds of sandstone. The upper part of the Lance is differentiated as the Ludlow lignitic member, because it is slightly different in general character from the underlying beds and contains all the lignite beds in this part of the field. The member contains more light-colored sandstone and more sandy shale than the lower part of the formation and is possibly in part the time equivalent of the Cannonball marine member of the Lance formation farther east. Above the Lance is about 50 feet of yellow sandstone and shale, with interbedded thin limestones, all of which are assigned to the Fort Union formation. Along the bottoms of some of the larger creeks alluvium was found, but the areas are so small that they were not mapped.

No valuable bed of lignite occurs in the township, but several thin ones not shown on the map are exposed. In secs. 32 and 33 there is a small amount of red rock, which is the result of the burning of a thin lignite bed. It is possible that at least part of the township is underlain by good lignite, as beds from 4 to 8 feet thick are exposed in the townships to the east and north.

T. 15 N., R. 8 E.

T. 15 N., R. 8 E., lies in the valley of Moreau River south of the Slim Buttes. The surface is gently rolling and for the most part covered with grass. The lack of sufficient rainfall or surface water in this part of the field has prevented settlement, except by a few

sheep ranchers. The soft somber-colored shale of the Lance formation constitutes the surface rock of that part of the township north of the river and is not lignite-bearing. On one of the low terraces along Moreau River, in the southern part of the township, there are numerous areas covered by subangular bowlders of hard gray quartzite similar to those scattered over the surface in many other parts of the field.

T. 16 N., R. 8 E.

The Slim Buttes, in the northern half of T. 16 N., R. 8 E., stand out as a high mesa 500 feet above the surrounding country. The south face of the buttes (Pl. IV, *B*, p. 32) is little dissected but rises as an almost impassable wall, extending in an easterly direction across the township. Along the east face, however, several small streams have cut into the cliff, producing narrow, steep-walled canyons. Immediately south of the buttes the surface is deeply dissected and exposures of rock are numerous, but the bedrock structure is greatly obscured by landslides. The southern part of the township is gently undulating and is covered with grass, so that exposures of rock are scarce. Numerous small farms have been established along the southern edge of the area, but the scarcity of water is proving a great hindrance to the raising of crops. Several good springs along the margin of the buttes have been utilized by the ranchmen, who years ago located where water was most accessible.

The lower part of the Lance formation, which contains no lignite, except near the top, is exposed in the area south of the Slim Buttes, where it weathers to sandy soil. The Ludlow lignitic member of the formation is represented by less than 50 feet of yellow sandy shale and sandstone outcropping at the base of the buttes. The White River and Arikaree (?) formations, which form the Slim Buttes, consist of about 200 feet of white clay, marl, sandstone, and conglomerate and overlie the lignite-bearing rocks unconformably. The rocks of the Lance dip gently to the northeast.

Several exposures of lignite were found near the top of the lower part of the Lance formation, which are interpreted as belonging to the same bed. At locations 475, 476, 477, and 478 the bed shows a thickness of good lignite ranging from 2 feet 6 inches (location 478) to 5 feet (location 476). The sections of the bed at these places are shown on Plate XI. No mining or prospecting has been done in the township.

T. 17 N., R. 8 E.

The surface of T. 17 N., R. 8 E., is varied. In the central and western parts the flat-topped J–B Hill and the Slim Buttes rise 300 to 400 feet above the surrounding area and stand out in marked contrast to the gently undulating grass-covered plain which is char-

acteristic of the Big Meadow to the east. The almost perpendicular cliff along the edge of the Slim Buttes mesa is deeply incised by numerous steep-sided canyons, so that the eastern margin of the mesa appears as a very irregular, almost impassable wall. A scanty growth of pine and cedar trees clothes the mesa and forms a valuable asset of the country.

Numerous small springs of good water issue from the sandstone near the base of the buttes and have been utilized by the few ranchers in the region. Very little farming has been done in this township, probably because of the roughness of the surface.

Along the margin of the buttes rock exposures are numerous, but owing to the great amount of slumping it is difficult to determine whether or not a bed is in its original position. The Lance, White River, and Arikaree (?) formations are all exposed in this township. The somber-colored shale of the lower part of the Lance formation occupies a small area along Antelope Creek, in the southeast corner of the township, and contains at one locality (location 479, sec. 25) a 3-foot bed of poor lignite. The Ludlow lignitic member of the Lance is composed of yellow shale, with soft yellow sandstone, some carbonaceous shale, and lenticular beds of fair-grade lignite. Unconformably above the Lance and forming the Slim Buttes and J. B. Hill is a series of white, light-gray, and pink clay, marl, and sandstone, which contains no lignite and is in places highly cross-bedded. The lower part is known to be of White River (Oligocene) age. The upper part is assigned to the Arikaree (?) sandstone because of its lithologic similarity to the Arikaree sandstone of southern South Dakota. The strata of the Lance formation in this part of the field dip gently northeastward.

The only two valuable lignite beds that are known to crop out in the township occur in the upper part of the Lance formation. The upper bed was measured at locations 494, 494B, and 495 to 501 and attains its maximum thickness of 6 feet at a small strip pit in sec. 8 (sec. 498, Pl. XI). All the sections obtained at the locations mentioned are shown graphically on Plate XI except that at location 501, which is as follows:

Section of lignite bed at location 501, in the SW. ¼ sec. 5, T. 17 N., R. 8 E.

	Ft.	in.
Lignite, weathered, full thickness not determined	1	9+
Shale, brown		1
Lignite		9
Shale, brown.		
Total section	2	7+
Total lignite	2	6+

The lower bed, about 30 feet below the one described above, is exposed at locations 502, 503, and 504 and has been mined for local use at location 503, in sec. 5. The sections measured at these places

(represented graphically on Pl. XI) show a variation in thickness from 2 feet 11 inches to over 4 feet 8 inches. At location 503 another bed 1 foot 8 inches thick is exposed 12 feet below the main bed. The two strip mines (locations 503 and 498) have been operated unsystematically by the ranchers near by to supply their own needs.

At many places in the township (see map, Pl. I) the lignite beds have burned along their outcrop, baking the overlying rocks to red scoria or clinker.

Several thin beds of lignite are exposed at various places in the township, but their stratigraphic relations to one another and to the thicker beds were not determined. The following measurements show their character and thickness:

Section of thin lignite beds in the Ludlow lignitic member of the Lance formation exposed in T. 17 N., R. 8 E.

[Not shown on Pl. XI.]

No. on Pl. I.	Location.	Section.	Ft.	in.
480	NE. ¼ sec. 28..	Shale, light brown, sandy.	12	0
		Shale, brown.....		8
		Lignite.....		½
		Shale, brown..		6
		Lignite.....	1	8
		Shale, brown.		
		Total section	14	10½
		Total lignite.	1	8½
481	SW. ¼ sec. 21..	Shale, brown.....	1	5
		Lignite.....	1	8
		Shale, brown.		
		Total section	3	1
		Total lignite.	1	8
482	SW. ¼ sec. 21..	Shale, light brown.	8	0
		Shale, brown.....		4
		Lignite.....	2	3
		Shale, brown.		
		Total section	10	7
		Total lignite.	2	3
483	SE. ¼ sec. 21...	Clay, sandy.		
		Shale, brown.....		4
		Lignite.....	1	5
		Shale, brown.		
		Total section	1	9
		Total lignite.	1	5
484	NW. ¼ sec. 22..	Soil.....		8
		Lignite.....	1	4
		Shale, light brown, clayey.		
		Total section	2	0
		Total lignite.	1	4
485	SW. ¼ sec. 22..	Clay, sandy.		
		Lignite.....	2	0
		Shale, brown.		
486	SW. ¼ sec. 22..	Clay, sandy.		
		Lignite.....	1	2
		Shale, brown.		
487	SW. ¼ sec. 22..	Clay, sandy.		
		Lignite.....	2	0
		Shale, brown.		
488	SW. ¼ sec. 14..	Shale, reddish brown, sandy; some gravel.	1	0
		Lignite.....	1	8
		Shale, brown.		
		Total section	2	8
		Total lignite.	1	8
489	NW. ¼ sec. 14..	Shale, light brown, sandy, and clay.	4	6
		Shale, brown.....	2	4
		Lignite.....	1	2
		Shale, brown.		
		Total section	8	0
		Total lignite.	1	2
490	NW. ¼ sec. 14..	Shale, light, sandy.	2	6
		Lignite.....		8
		Interval.....	7	0
		Lignite.....	2	0
		Shale, brown.		
		Total section	12	2
		Total lignite.	2	8
491	NE. ¼ sec. 17..	Shale, brown.....		4
		Lignite.....	1	9
		Shale, brown.		
		Total section	2	1
		Total lignite.	1	9
492	SE. ¼ sec. 10...	Clay, sandy.		
		Lignite.....	1	6
		Shale, brown.		
493	SE. ¼ sec. 10...	Clay, sandy.		
		Shale, brown.....		6
		Lignite.....	2	4
		Shale, brown.		
		Total section	2	10
		Total lignite.	2	4
494A	SW. ¼ sec. 16..	Clay, sandy.		
		Shale, brown.....		6
		Lignite.....	1	6
		Shale, brown.		
		Total section	2	0
		Total lignite.	1	6

Of these sections, 480, 481, and 482 are supposed to be on one bed, 485, 486, and 487 on another, and 489 and 490 on a third.

T. 18 N., R. 8 E.

T. 18 N., R. 8 E., lies at the west margin of the Big Meadow and includes a portion of the Slim Buttes, which rise abruptly 300 feet or more above the surrounding plain. Around these buttes the surface is gently rolling, although close to the cliff line streams have dissected the area until at places it is almost impassable. In the eastern half of the township the surface is gently rolling and grass covered, and numerous small farms have been established in the last few years. Large springs of excellent water issue from rocks near the base of the buttes and have been used by the ranchers of the region as watering places for large herds of cattle and horses. Among these, the spring at the old L ranch in sec. 28 is probably the best known.

The lower portion of the Lance formation is exposed in a small area in sec. 18, in the valley of Sioux Creek west of the Slim Buttes. Above and almost inseparable from these beds is the Ludlow lignitic member of the Lance, which is composed of yellow sandy shale and soft sandstone, with some carbonaceous shale and lignite. In the Slim Buttes it is overlain unconformably by the White River formation and this, in turn, by the Arikaree (?) sandstone, neither of which is lignite-bearing. These formations include more than 300 feet of light-colored clay, marl, sandstone, and conglomerate, and the lower part is in places markedly cross-bedded. Cross-bedding is especially conspicuous in Reva Gap, in sec. 17, and south of the old L ranch, in sec. 32.

Along the east side of the buttes rock slumps and landslides have rendered the interpretation of the structure and the correlation of the lignite beds very difficult. The Lance and the underlying formations, however, appear to dip to the northeast at angles ranging from about 15 feet to the mile in the western part of the township to 35 feet to the mile in the eastern part.

East of the Slim Buttes, in the southern part of the township, two beds of lignite reach a thickness of 3 feet or more at several places along their outcrops. The upper bed, illustrated by sections 505 to 510, Plate XI, attains a maximum thickness of 4 feet 11 inches at location 508, in sec. 28, where near-by ranchers have mined lignite for their own use. The same bed at location 511, only a short distance to the northeast of location 510, is less valuable, as shown by the following section:

Section of lignite bed at location 511, in the SW. ¼ sec. 21, T. 18 N., R. 8 E.

	Ft.	In.
Shale, drab.		
Lignite		8
Shale, brown		2
Lignite	1	1
Shale, brown.		
Total section	1	11
Total lignite	1	9

The second bed, 25 feet lower, is represented by sections 516 to 519, Plate XI, and ranges in thickness from 2 feet 6 inches at location 519 to 6 feet 10 inches at location 516. This bed has not been mined. Lignite beds more than 2 feet 10 inches thick are exposed at locations 515 and 520, but the extent of the beds beyond the exposures is not known. A lignite bed more than 2 feet in thickness has been stripped at location 521, in sec. 22, and several wagon loads of fuel have been removed, but probably there is no great area of lignite here, as the rocks in this vicinity are much disturbed and the lignite bed is probably included in a landslide.

In the northern part of the township three beds of lignite attain a thickness of more than 2 feet 10 inches. The upper one, along its outcrop, increases in thickness from 2 feet 6 inches at location 525, in sec. 16, to 6 feet at location 526, in sec. 17, and then diminishes to 2 feet 1 inch at location 527, also in sec. 17. About 10 feet below this bed, in sec. 8, a second bed (represented by sections 530 and 531, Pl. XI) has been mined on a small scale at location 531, where it is 4 feet 6 inches thick. A third bed, about 40 feet below the second, is exposed at locations 528 and 529. At location 528, in sec. 8, it has been mined on a small scale and is more than 9 feet thick. At location 529, in sec. 4, a bed supposed to be at the same horizon has a thickness of at least 5 feet.

In addition to the sections shown graphically on Plate XI the following represent thin, nonpersistent lignite beds that are exposed in T. 18 N., R. 8 E., east of the Slim Buttes.

Sections of thin lignite beds exposed on the east side of Slim Buttes in T. 18 N., R. 8 E.

[Not shown on Pl. XI.]

No. on Pl. I.	Location.	Section	Ft.	in.
512	SW. ¼ sec. 33..	Shale, brown.		
		Lignite.....	1	6
		Shale, brown....		4
		Lignite.....		11
		Shale, brown		
		Total section..	2	9
		Total lignite...	2	5
513	NE. ¼ sec. 33..	Shale, brown.....	1	3
		Lignite.....	2	6
		Shale, brown.		
		Total section..	3	9
		Total lignite...	2	6
522	NW. ¼ sec. 23..	Clay, sandy.		
		Lignite.....		10
		Shale, brown....	1	5
		Lignite.....		8
		Shale, brown.		
		Total section..	2	11
		Total lignite...	1	6
523	SW. ¼ sec. 15..	Lignite.....	1	6
		Shale, light, sandy	1	2
		Lignite.....	2	0
		Shale, brown.		
		Total section..	4	8
		Total lignite...	3	6
524	SW. ¼ sec. 15...	Shale, light, sandy.		
		Lignite.....	1	9
		Shale, brown.		
532	SE. ¼ sec. 9....	Sandstone, brown...	2	0
		Lignite.....	2	0
		Shale.		
		Total section..	4	0
		Total lignite...	2	0
533	NW. ¼ sec. 11..	Shale, brown.		
		Lignite.....	2	3
		Shale, brown.		

On the west side of the Slim Buttes lignite beds ranging in thickness from 4 feet at location 537 to 2 feet 6 inches at location 538 are

exposed at a number of places. Sections 534 to 541, 543, shown on Plate XI, give an idea of their thickness and character. At location 542 the following section is exposed:

Section of lignite bed at location 542, sec. 28, T. 18 N., R. 8 E.

	Ft.	in.
Shale.		
Lignite		4
Shale	1	9
Lignite		5
Shale		10
Lignite	1	3
Shale.		
Total section	4	7
Total lignite	2	0

One small mine has been opened at location 535, in sec. 20, but only a lew loads of lignite have been removed.

T. 19 N., R. 8 E.

The surface of T. 19 N., R. 8 E., is exceedingly rough and shows a maximum difference in altitude of 700 feet. The flat-topped mesa of the Slim Buttes, which occupies the southwest corner of the township, terminates in a steep, almost impassable cliff more than 200 feet high. Between this cliff and the open valley of the South Fork of Grand River, at the northern boundary of the township, the surface is deeply dissected into numerous narrow, rugged coulees. Dark-red scoria resulting from the burning of lignite appears in marked contrast to the nearly pure white clay and sandstone of the White River and Arikaree (?) formations, and where slumping has brought the two into contact the contrast is especially striking. With the exception of a small area in secs. 35 and 36, this township is too rough to be used for farming.

The somber-colored shale of the lower part of the Lance formation crops out in the small valleys in the northern part of the township. It is overlain by the Ludlow lignitic member of the Lance, which is composed of about 165 feet of yellow sandstone, yellow shale, carbonaceous shale, and lignite. The White River and Arikaree (?) formations constitute the Slim Buttes and rest unconformably on the Ludlow member. The White River, about 60 feet thick, is composed of white and light-colored clay and thin beds of sandstone, and the Arikaree (?), about 180 feet thick, is composed of soft white tuffaceous sandstone with some conglomerate.

Rock exposures are numerous in the area north of the Slim Buttes, but landslides have so greatly disturbed the surface rock that it is almost impossible to correlate lignite beds or correctly interpret geologic structure. One of the most noticeable landslides in the field is in sec. 20, where a block of White River beds half a mile long, 500

feet wide, and about 125 feet thick, has moved down laterally until now it occupies the bottom of a valley where it is surrounded by rocks of the Lance formation. (See Pl. III, *B*, p. 10.) Many less extensive landslides, affecting not only the White River but also the lignite-bearing formation of the field, have occurred in the township. The lower rocks dip eastward about 70 feet to the mile in the western part of the township, but the dip decreases to about 10 feet to the mile in the eastern part.

Only a few settlers live in the vicinity, and therefore the demand for lignite is small. The Bar H mine, which is the only one that has been opened in the township, is in sec. 27 (location 544). A wagon road has been constructed to this mine, and considerable fuel has been removed by stripping.

The most valuable lignite bed and the only one whose outcrop can be followed with a fair degree of certainty is exposed at the base of the Slim Buttes, only a few feet beneath the White River formation, and may have been destroyed locally by erosion before the deposition of the younger formation. The thickness at locations 544, 545, and 547 to 550 along its outcrop varies from 3 feet 5 inches at location 550, in sec. 19 (see Pl. XI), to 13 feet 8 inches at location 544, in sec. 27.

Thick beds of lignite are exposed at a number of places in the township, measurements of which are shown graphically on Plate XI. Sections 563 to 570 were measured along the outcrop of a bed near the base of the Slim Buttes that ranges in thickness from 2 feet 2 inches at location 563 to 6 feet 1½ inches at location 564. The bed at the base of the Ludlow lignitic member of the Lance (locations 572 to 575) is of little value in this township. Even though it reaches a maximum thickness of 3 feet 2 inches at location 574 (Pl. XI), it is so thin at every other place where it was seen that it can not be considered of commercial importance. The exact correlation of lignite beds in most other parts of the township is impossible. Sections 557 and 558 are supposed to belong to one bed, sections 559 and 560 to another, 576 and 577 to another, and 578 and 579 to still another. Sections 546, 551 to 555, 561 and 562 (Pl. XI) represent lignite beds having a thickness of more than 2 feet 10 inches, but on account of poor exposures the outcrops could not be connected or the beds correlated. The following sections of thin beds were made at places indicated on the map (Pl. I):

Sections of thin lignite beds in T. 19 N., R. 8 E.

[Not shown on Pl. XI.]

No. on Pl. I.	Location.	Section.	Ft.	in.
556	NE. ¼ sec. 22..	Shale, brown.		
		Lignite	1	7
		Shale, brown.		
571	SW. ¼ sec. 18..	Shale, brown.		
		Lignite, dirty		8
		Shale, brown	3	2
		Lignite		6
		Lignite, dirty	1	9
		Shale, brown.		
		Total section	6	1
		Total lignite	2	11
572	NW. ¼ sec. 7...	Shale, brown.		
		Shale, carbonaceous		4
		Shale		3
		Lignite		4
		Shale, brown		4
		Lignite	2	8
		Shale, brown.		
		Total section	3	11
		Total lignite	3	0
578	NE. ¼ sec. 10..	Shale, brown.		
		Lignite	2	5
		Shale, brown.		
579	NW. ¼ sec. 15..	Shale, brown.		
		Lignite		7
		Shale, brown		3
		Lignite	2	3
		Shale, brown.		
		Total section	3	1
		Total lignite	2	10

T. 20 N., R. 8 E.

T. 20 N., R. 8 E., drains into the South Fork of Grand River, which meanders through the southern part of the township in an open valley. After heavy showers and during the spring thaws the river becomes a torrential stream, owing to the very rapid run-off of the water. Skull Creek drains the northwest corner of the township, Brushy Creek the middle, and Horse Creek the western part. These three intermittent streams flow in a general southeasterly direction, which is roughly parallel to the strike of the rocks. The maximum difference in altitude in this area is about 600 feet, the highest points, almost 3,200 feet above sea level, being near the northwest corner, in secs. 4 and 5. The surface of the township is very rough and is not suitable for cultivation. Narrow, high rocky divides separate the small streams that cross the township and almost prevent travel from one valley to the adjoining one. Although a number of homesteaders have recently taken up claims in different parts of the area, little successful farming is to be expected, even with dry-farming methods, except in a few small areas along the larger streams. Most of the land along the South Fork of Grand River is too sandy to make good farm land, and although the river is a perennial stream, only a very small amount of water is available for irrigation, especially during the season when it is most needed.

A few old ranches are situated in the more favorable localities, and the area will probably continue to be used as grazing land for cattle and horses. Bratsburg post office is in sec. 8.

About 600 feet of strata are exposed in this township. They belong almost entirely to the Lance formation, although there may be a small

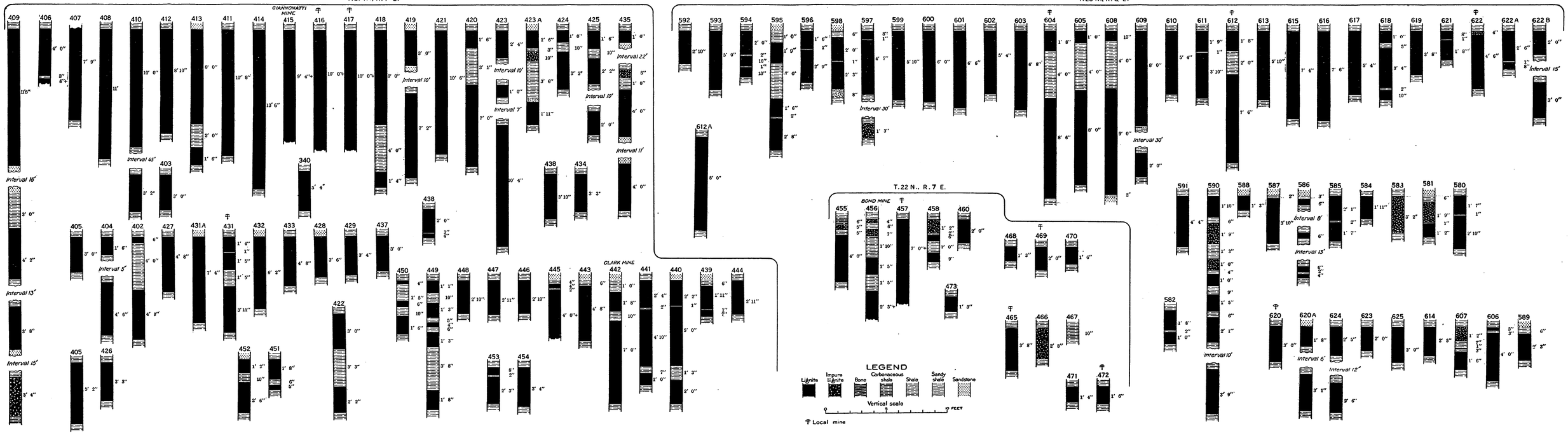
thickness of Fort Union rocks on the highest points in the northwest corner. The lithologic difference between the two formations is so slight that in a grass-covered area it is impossible to separate them. The lower part of the Lance formation is present in the valley of the South Fork of Grand River, but alluvium and sand obscure the rocks so that a study of their character is difficult. Immediately below the lowest lignite bed, which is assumed to be the base of the Ludlow lignitic member, the formation is composed of dark-colored clay shale, with a few lenses of sandstone and beds of carbonaceous shale. They are in places much cross-bedded. Above this lignite bed the rocks are more sandy and light colored and contain numerous lignite beds, one of which outcrops along the ridges in this and adjacent townships and has been mined at a number of localities. The dip is northeast, probably not more than 20 feet to the mile, as determined by altitudes on the main lignite bed.

There are at least four lignite beds worthy of note in this township; two of them are of good thickness and quality, but the other two are of questionable commercial value. The lowest bed outcrops along the north side of the South Fork of Grand River at locations 580, 581, 583 to 588, 590, and 591 (see Pl. VIII) and is of little worth; in fact, at locations 581, 583, 586, and 588 it is not much more than carbonaceous shale.

Along the stream bank at locations 585 and 587, in sec. 27, the bed is more than 3 feet thick, and at location 580, in sec. 29, it is 4 feet 6 inches thick. A local lens of lignite above the lowest bed has a thickness of 2 feet 10 inches at location 582, in sec. 21, but is not exposed elsewhere.

Along Skull Creek near the Henry ranch, in sec. 11, is the outcrop of a lignite bed nearly 200 feet above the one just mentioned, which ranges in thickness from 2 feet at location 623, in sec. 24, to 3 feet at location 620, in sec. 11. (See sections 620, 620A, 623, 624, and 625, Pl. VIII.) Beds exposed at locations 589, 606, 607, and 614 are supposed to represent the same bed. Of these the bed exposed at location 606 is the thickest, measuring 4 feet 6 inches. The bed has been worked locally at a small opening (location 620) about half a mile above the Henry ranch.

Nearly 100 feet above the second bed is another, represented by sections 592 to 605, 608 to 613, 615 to 619, and 621 to 622B, Plate VIII, which is supposed to be the same as the Widow Clark lignite of T. 21 N., R. 7 E. Its thickness ranges from about 2 feet at location 622B, in sec. 12, to 9 feet at location 608, in sec. 23. At most places along the outcrop the bed contains more than 4 feet of good lignite. Three small strip pits have been opened on it—one at location 622, in sec. 1; another at location 612, in sec. 9; and a third at location 604, in sec. 22. The lignite is of about the same quality as the sample



LIGNITE SECTIONS IN HARDING COUNTY, S. DAK.

In area examined by C. J. Hares.

taken from this bed at the Newcomb mine, in T. 20 N., R. 9 E., which shows about 12 per cent of ash and a heating value of 8,520 British thermal units in an air-dried sample. About 100 feet above the Widow Clark lignite bed is the one locally called the Giannonatti bed, which is well exposed in T. 21 N., R. 7 E. This bed at the east side of sec. 9 of this township (location 612A) contains 8 feet of good lignite. The bed has been burned at several places, giving rise to large masses of red fused rock, particularly in secs. 1, 4, 9, 16, and 22. In secs. 22 and 16 large masses of baked rock cap the divide and may be seen for several miles, standing out like high red signals. The bed underlies small areas in secs. 1, 4, 5, 8, and 9, but in adjacent areas in both North and South Dakota, the bed averages about 5 feet in thickness and underlies large areas.

T. 21 N., R. 8 E.

T. 21 N., R. 8 E., for the most part drains almost directly into Big Nasty Creek, which flows southeastward across the township from the northwest corner in a broad, open valley. The southern part of the township drains into Skull Creek. Through the southern part extends a high dissected ridge, locally known as the Circle Hills, with altitudes ranging from 3,000 to 3,200 feet above sea level. The surface of the rest of the township is uneven but grass-covered, so that rock exposures are scarce.

Although the surface of the township is very rough, it is fairly well settled. At Ralph, a small settlement at the old Howard ranch, in sec. 24, there is a combination store and post office. As a whole the township seems better adapted to grazing than to dry farming, because most of it is too hilly to be conveniently cultivated. The narrow strip of bottom land along Big Nasty Creek may possibly be farmed by irrigation, but the supply of water is meager, for in dry times the creek does not contain running water. Farmers depend largely on wells for water, and what they get is mostly alkaline.

Of the 500 feet of rocks exposed in this township the lower 300 feet belong to the Ludlow lignitic member of the Lance formation, and the upper 200 feet is assigned to the Fort Union formation. The Lance in this township is composed of dark-colored, sandy and carbonaceous shale, coarse-grained, brownish to gray sandstone, and lignite. South of Big Nasty Creek, near the center of the township, one of the indurated sandstones forms the top of a prominent ridge. The sandstone has been used for buildings.

The Fort Union formation, which is present on the upland in the northeast corner of the township and in a high hill in sec. 31, is composed of light-colored sandstone with a few thin beds of shale. No lignite is known in the formation in this part of the field, but to the north and east the Fort Union contains some of the best lignites of the Dakotas.

Along the valley of Big Nasty Creek there is considerable alluvium derived from the rocks of the surrounding country.

The rock strata in this township are very nearly horizontal, but the altitudes determined on the Widow Clark lignite in the valley of Big Nasty Creek indicate a slight but regular dip to the northeast.

Several beds of lignite are exposed in the township. The lowest one mapped is the Widow Clark lignite, which is exposed at a number of places and has been worked at three small strip mines. Although the mantle of grass and soil obscures the outcrop of lignite beds and makes the correlation of exposures very difficult, the beds at locations 631 to 633, 647, 650 to 653, 655 to 657B, and 661 to 674 are supposed to represent the Widow Clark lignite in this township. The bed varies greatly in thickness from place to place, as will be seen by reference to the graphic sections on Plate IX. The maximum thickness measured is at location 667, in sec. 6, where the bed is 8 feet thick and the upper part is poor lignite. Several wagon loads of fuel have been mined by stripping from each of the small mines at locations 632, 653, and 667.

About 20 feet above the Widow Clark is the Bell bed. Measurements at locations 644, 645, 646, 648, 649, 654, 658, and 659, shown graphically in Plate IX, are probably on this lignite bed, although absolute correlation is impossible. The bed ranges in thickness from 10 inches at location 646, in the center of sec. 26, to 5 feet at the Bell mine at location 648, in the NE. ¼ sec. 27. At location 645, in the SW. ¼ sec. 25, there is a second prospect. The quality of the lignite in this bed is fair.

About 22 feet above the Bell bed occurs a third, along the outcrop of which sections 634, 635, 636, 638, and 639 were measured. Its thickness ranges from 1 foot 6 inches at location 634 to more than 4 feet at location 639. West of location 634 the bed is of little value and was not mapped.

About 70 feet above the Bell bed is the Giannonatti bed, which is exposed at locations 630, 637, 629A, 629B, 628, 627, and 641. At location 637 the bed is only 2 feet 4 inches thick, but elsewhere it is much thicker, as is shown graphically by the sections on Plate IX, and is thickest at the Shirley mine (location 629B), in sec. 35, where the following section is exposed:

Section of lignite bed at Shirley mine, sec. 35, T. 21 N., R. 8 E.

	Ft.	in.
Shale.		
Lignite	7	10
Shale		10
Lignite	5	9
Sandstone.		
Total section	14	5
Total lignite	13	7

Considerable lignite has been taken from this mine for local use. The lignite encountered at a considerable depth in a well located in sec. 1 and reported to be about 6 feet thick may be this bed or possibly the Widow Clark bed.

T. 22 N., R. 8 E.

The most marked surface features of T. 22 N., R. 8 E., are the Lodgepole Buttes, in the extreme eastern part. These buttes form the culmination of the divide that stretches westward and separates the drainage, part of which flows southward by small tributaries into Big Nasty Creek and the remainder by small tributaries into the North Fork of Grand River. The divide is a part of the more or less extensive table-land that surrounds the Lodgepole Buttes. The altitude of the highest butte is 3,222 feet above the sea level, or about 200 feet above the general level of the surrounding country. The surface of the township is for the most part broken and grass-covered, but here and there, as along the south and north sides, deep valleys are encroaching on the upland area. Nearly all the land has been taken up in homesteads, but only ordinary crops of grain have been raised. The land produces an abundance of natural grass that furnishes excellent grazing, and stock raising so far is the most profitable industry.

The Lance formation, consisting of interbedded shale, sandstone, and lignite, is exposed in the Cadyville Valley, in the northern part of the township, and south of the divide in the southwest corner. In the Cadyville Valley and in sec. 2 part of the strata are assigned to the Cannonball marine member of the Lance; the remaining portion of the Lance is referred to the Ludlow lignitic member because it contains lignite beds. The upper 300 feet of beds exposed, consisting of shale, sandstone, and limestone, somewhat lighter colored than those of the Lance, belong to the Fort Union formation. The upper part of the Fort Union is a brown massive, somewhat coarse-grained sandstone. This phase of the Fort Union is well developed in the cap of the Lodgepole Buttes. Here and there along the west slope of the buttes are quartzite bowlders that have been derived from the quartzitic stratum in the Fort Union.

Two lignite beds were mapped in this township. The lower and thinner one outcrops in secs. 33, 34, and 35, and the only data regarding its thickness were obtained from the wells at locations 676 and 677, where it is reported as 2 feet 9 inches and 2 feet 4 inches thick, respectively. It is also reported as 4 feet thick in a well at location 675, in the NW. ¼ sec. 3 of the township immediately to the south. The sections of this bed are shown graphically on Plate IX. A thick bed of fair quality, supposed to be the same as the Giannonatti bed in T. 21 N., R. 7 E., is separated from the thin bed by about 30 feet of shale and sandstone. The bed has an average thickness of about

6 feet, ranging from 3 feet 8 inches at location 680, in sec. 29, to 12 feet (well record) at location 678, in the SW. ¼ sec. 27. It is mined on a small scale at location 684, near the center of sec. 9. The sections of the lignite bed at locations 678, 678A, 680, 681, 683, 684, 685, and 686 are shown graphically on Plate IX. There is some doubt whether the bed at an average altitude of 2,850 feet at locations 683, 684, 685, and 686, in the northwest corner of the township, is the same as the one on the south side of the divide, which occurs at an altitude of 2,840 to 2,865 feet, but if it is, the formations and lignite beds in this township lie nearly flat. The 3 feet of lignite reported to have been struck at a depth of 40 feet in a well at location 679, in the southwest corner of sec. 28, may possibly be on this bed, as is the 6 feet of lignite reported in the well 40 feet deep at location 681, in the NW. ¼ sec. 32. A third bed of lignite may underlie the Lodgepole Buttes, for in the township to the east such a bed has been prospected at two localities and is 4 feet thick.

T. 23 N., R. 8 E.

The surface of T. 23 N., R. 8 E., as a whole, is gently rolling, but exhibits a few rather steep slopes, which are due to resistant beds of sandstone and limestone. It may be described as a region in physiographic maturity, the uplands being completely dissected and well drained and the larger streams meandering on their flood plains. The drainage goes entirely into the North Fork of Grand River. The total relief is about 200 feet. About nine-tenths of the township may be classed as upland, and the rest as bottom land. The land seems to be pretty well suited to dry farming, and fair crops of flax and wheat are grown. There are many tracts of grassy land, and only one-quarter to one-half of the arable land has been broken. The small village of Cadyville is situated in the SE. ¼ sec. 32.

The oldest rocks exposed in this township are classified as the Ludlow lignitic member of the Lance formation. They are composed chiefly of dark, sandy shale and sandstone interbedded and contain one fairly good bed of lignite at the top. The total exposed thickness of this member is about 50 to 75 feet. The strata outcrop along the sides of the Cadyville Valley and along the valley in which the stage line runs from Haley, N. Dak., to Ralph, S. Dak., and occupy the greater part of the lowlands.

Between the Ludlow lignitic member of the Lance and the Fort Union formation, along the North Fork of Grand River and its tributaries, there is a series of rocks containing marine fossils, which is assigned to the Cannonball marine member of the Lance. No fossils were found in the member in this township, but near Bloom, in the township to the east and across the State line in North Dakota, marine fossils were found above the lignite bed. The rocks of the

Ludlow lignitic member and those of the Cannonball marine member are very similar lithologically, but the former contain lignite and other evidences of fresh-water deposition, whereas the latter contain marine fossils.

The Fort Union formation, which consists of sandstone and shale, covers a large portion of the township, including all the upland. Some of the sandstone beds are more resistant than others and cause the more or less abrupt breaks at the edge of the uplands. About 100 feet of the formation is present.

A deposit of alluvium about half a mile wide and 3 miles long occurs along the large creek leading from Cadyville to Haley.

For economic and stratigraphic purposes the strata of this township may be considered horizontal, but they have a very slight northeasterly dip, as determined by altitudes on the lignite bed traced from T. 22 N., R. 8 E., through T. 23 N., R. 8 E., to the State line, the dip of the bed apparently being just about the same as the gradient of the larger stream.

One bed of lignite is exposed at two or three places in this area; elsewhere its outcrop is concealed by soil and grass. At location 682 (see Pl. IX) in the SW. ¼ SE. ¼ sec. 21, the following section was measured:

Section of lignite bed at location 682, in the SW. ¼ SE. ¼ sec. 21, T. 23 N., R. 8 E.

	Ft.	in.
Shale.		
Lignite, dirty		4
Lignite	1	8
Shale		8
Lignite	1	8
Total section	4	4
Total lignite	3	8

Across the creek, at location 687, in sec. 28, there is a lignite bed exposed at about the same altitude, which has the following section:

Section of lignite bed at location 687, in sec. 28, T. 23 N., R. 8. E.

	Ft.	in.
Shale.		
Lignite	1	0
Shale		½
Lignite		11
Shale	3	0
Lignite		10
Total section	5	9½
Total lignite	2	9

In the township to the south the bed ranges from 2 feet 6 inches to about 7 feet in thickness. It is reported that a well in the NW. ¼ NE. ¼ sec. 26 struck at least 4 feet of good hard lignite, which may

represent the same bed. Although correlation of this bed with those exposed in neighboring townships is impossible, it is thought to be the same as the Giannonatti bed.

T. 15 N., R. 9 E.

T. 15 N., R. 9 E., is south of the east end of the Slim Buttes and includes Sheep Mountain, a high isolated butte which rises to an altitude of about 3,400 feet above sea level. The surface is very rough, and is fit only for grazing, having a relief of about 500 feet between the valley of Sheep Creek and the top of Sheep Mountain.

The lower part of the Lance formation constitutes the surface rocks of the township, except in a small area on the top of Sheep Mountain. The soft somber-colored shale of this formation has been eroded into intricate badlands. The Ludlow lignitic member of the Lance is represented beneath the White River formation in Sheep Mountain by about 35 feet of yellow sandy shale and soft sandstone, with a thick bed of lignite at the base. The White River formation, about 100 feet thick, occupies the small area at the top of Sheep Mountain and consists of soft white marl and thin beds of sandstone.

The only bed of lignite exposed in the township occurs at the base of the Ludlow lignitic member of the Lance. At location 688, in sec. 8, it is 1 foot 6 inches thick, but the area underlain by it is very small and almost inaccessible.

T. 16 N., R. 9 E.

The surface of T. 16 N., R. 9 E., is gently rolling and grass-covered, except in the western part, where the southeast end of the Slim Buttes rises in an almost impassable cliff 400 to 500 feet above the plain. The nearly flat top of the mesa is covered by a dense growth of grass, together with a few pine and cedar trees, but the plains east and north of the buttes are almost treeless. The land in the latter area has been settled by farmers who can, by the use of proper dry-farming methods, raise crops of wheat, oats, flax, etc. The JX ranch, in the valley of Antelope Creek, is one of the oldest stock ranches of the region.

The soft shale of the lower part of the Lance formation forms the surface rock in the largest part of the township. The Ludlow lignitic member of the Lance, represented by about 75 feet of yellow sandy shale and soft sandstone, is exposed around the edge of the Slim Buttes mesa and on the divide north of the JX ranch. Above this, in the Slim Buttes, is a mass of white clay, marl, sandstone, and conglomerate about 200 feet thick, which is assigned to the White River and Arikaree (?) formations. The rocks in the vicinity of the Slim Buttes, especially along their southern face, are much

disturbed, and the true structure is obscured by landslides. In the valley and plains part of the area the rock structure is obscured by a heavy mantle of soil.

Several isolated exposures of lignite were found near the base of the Ludlow lignite member of the Lance formation, but owing to the slumping it was impossible to make exact correlations, hence the exposures are shown on the map as unconnected outcrops. At a single place (location 692; see Pl. XI) the lignite has a thickness of 3 feet. No prospecting or mining has been done in this township. The following sections of thinner beds were measured, but are not shown on Plate XI:

Sections of lignite beds in T. 16 N., R. 9 E.

No. on Pl. I.	Location.	Section.	Ft.	in.
689	NE. ¼ sec. 30..	Lignite.....	2	0
690	NW. ¼ sec. 29..	.....do.....	1	11
691	SE. ¼ sec. 29...	.....do.....	1	9
693	SW. ¼ sec. 22..	Lignite.....	1	0
		Interval.....	10	0
		Lignite.....	2	0
		Total section.	13	0
		Total lignite..	3	0
694	SW. ¼ sec. 16..	Lignite.....	1	4

T. 17 N., R. 9 E.

The gently undulating prairie which is characteristic of this part of the field is surmounted in the southwest corner of T. 17 N., R. 9 E., by Flat Top Butte, a small mesa which stands nearly 200 feet above the surrounding country. The soil in most of the township is a rich sandy loam, and crops of small grains have been raised on a number of small farms recently established in the township. An excellent spring in sec. 32 issues from rocks near the base of the White River formation.

The lower part of the Lance formation occupies a large area in the valleys of Rabbit Creek and its tributaries and along the south edge of the township. The Ludlow lignite member of the Lance is represented by a small thickness of sandy shale and thin-bedded sandstone, occupying the higher portions of the township, except in Flat Top Butte, where about 100 feet of the White River and Arikaree (?) formations is exposed. At the northwest angle of the butte the clay and sandstone of the White River formation show very marked cross-bedding, with angles of 20° to the horizontal. The bedrock in this part of the field is almost wholly obscured by the heavy mantle of soil, but from a study of a few exposures in this and adjacent townships the rock structure was determined. The rocks of the Lance formation dip to the northeast at about 40 feet to the mile.

The only lignite bed exposed in the township shows the following section:

Section of lignite bed at location 695, in sec. 25, T. 17 N., R. 9 E.

	Ft.	in.
Shale, brown.		
Lignite		2
Shale, brown	2	6
Lignite	1	6
Shale, brown.		
Total section	4	2
Total lignite	1	8

A well drilled in the NE. ¼ SE. ¼ sec. 25 is reported to have passed through the following formation:

Record of well in NE. ¼ SE. ¼ sec. 25, T. 17 N., R. 9 E.

	Ft.	in.
Soil	4	0
Clay, blue	10	0
Sandstone, hard	4	0
Lignite		8
Sandstone, hard	36	0
Clay, greenish, sticky, with occasional partings of sandstone	36	0
Lignite		6
Clay, greenish, sticky, with occasional partings of sandstone	30	0
Total section	121	2
Total lignite	1	2

Evidently this well passed through the Ludlow lignitic member of the Lance into the somber-colored shale of the lower part of the formation.

T. 18 N., R. 9 E.

The surface of T. 18 N., R. 9 E. is gently rolling and in large part cultivated, so that the underlying rocks are exposed in only a few places. The soil, which has resulted from the disintegration of soft sandstone and sandy shale, is a rich sandy loam and is well adapted to the raising of wheat, flax, rye, and oats, as well as potatoes and other garden products. At the time of examination in 1911 very few quarter sections of land in this township remained uncultivated. A few rather prominent but small rugged buttes rise above the general level of the plain and constitute well-known landmarks.

The somber-colored shale of the Lance formation outcrops in the valley of Gap Creek, in secs. 35 and 36, and the Ludlow lignitic member forms the surface rock in the remainder of the township except for a small area of the White River formation in the tops of low hills in sec. 5. The beds of the Lance formation dip to the northeast at about 25 feet to the mile.

A bed of lignite outcrops along the stream in sec. 4, and sections of it are given below, but it does not attain valuable thickness in the

township, and its correlation with the beds exposed in the township to the north is not known because the rocks between the exposures are covered by soil and grass.

Sections of lignite bed exposed in sec. 4, T. 18 N., R. 9 E.

No. on Pl. I.	Location.	Section.	Ft.	in.	No. on Pl. I.	Location.	Section.	Ft.	in.
699	NW. ¼ sec. 4..	Shale, brown.			701	NE. ¼ sec. 4...	Clay, yellow, sandy.		
		Lignite.....	1	10			Lignite.....	1	6
		Shale, brown.					Shale, brown.....	7	0
700	NW. ¼ sec. 4..	Clay, yellow, sandy.					Lignite.....	1	0
		Shale, brown.....		5			Shale, brown.		
		Lignite.....	1	6			Total section.	9	6
		Shale, brown.					Total lignite.	2	6
		Total section.	1	11					
		Total lignite.	1	6					

Near the tops of three rather prominent buttes in secs. 10, 11, and 33 a bed of lignite is exposed, which attains a total thickness of 4 feet of good lignite separated into two benches at one locality (No. 698, Pl. XI), but the bed underlies only a small area at the top of the butte and has only 20 or 30 feet of cover, hence is of little commercial value. Other sections exposed on this bed are as follows:

Sections of upper lignite bed exposed in T. 18 N., R. 9 E.

No. on Pl. I.	Location.	Section.	Ft.	in.	No. on Pl. I.	Location.	Section.	Ft.	in.
696	SE. ¼ sec. 32...	Sandstone.			697	SE. ¼ sec. 11...	Clay, yellow, sandy.		
		Shale, brown.....	1	3			Lignite.....	2	5
		Lignite.....		4			Shale, brown.		
		Shale, brown..	1	6					
		Lignite.....	1	9					
		Shale, brown.							
		Total section.	4	10					
		Total lignite.	2	1					

This bed is probably the same as that which underlies two small hills in secs. 34 and 35 of the township to the north.

T. 19 N., R. 9 E.

The South Fork of Grand River, which crosses three sections in the northern part of T. 19 N., R. 9 E., is one of the few perennial streams of the region and occupies a broad, open valley through which it flows in a widely meandering course. The run-off from the township is carried by this river. Between the level of the river in sec. 2 and the highest points to the south, in sec. 32, at 3,070 feet above the sea, there is a difference in altitude of about 400 feet. One very striking topographic feature in this part of the field is the flat-topped hills that are capped by thin beds of resistant sandstones. These are

especially prominent in secs. 9, 10, 15, and 16. The surface of the township is deeply dissected by numerous small streams, so that areas suitable for cultivation are scarce and most of the township is still used for grazing. The Ronan ranch, in sec. 11, is the only large ranch in the area, and only a few of the homesteaders who have recently taken up land have met with sufficient success to allow them to remain. Excellent springs issue from the sandstone ledges in the vicinity of Hogarth ranch, which is in sec. 4 of the township to the south. Only a few wagon roads and trails traverse the area, and these follow the easiest routes laid out by the old settlers. Most of the roads lead to Reva post office, in the township to the west.

Nearly all the rocks exposed in this township belong to the Lance formation. The lower rocks along the river consist of somber-colored cross-bedded sandy shale, with carbonaceous beds that locally merge into lignite. Above this part of the section the strata are yellow and more sandy and contain several beds of indurated ripple-marked cross-bedded sandstone, which give rise to very rough topographic features. This series, about 350 feet thick, is referred to the Ludlow lignitic member of the Lance and embraces all the valuable beds of lignite that are found in this part of the field.

Small erosion remnants of the White River formation are preserved in secs. 32 and 33. The rocks are almost white, some of them greenish white, and in the main are clay and fine-grained sandstone containing siliceous lentils. Along the main drainage channels there are some recent deposits of sand and alluvium.

Considered as a whole, the strata of this township are essentially horizontal, though there is an apparent northeasterly dip of about 15 to 30 feet to the mile. Here and there the beds are disturbed more than usual, some of them dipping as much as 5°. At first sight this condition seems to be due to local folding, but it may indicate the slope on which the sediments were deposited or it may possibly be due to the slipping of the unconsolidated material out from one side of a hill, allowing the cap of sandstone to settle unequally.

Four beds of lignite occur in this township. The lowest one is on the south bank of Grand River, and measurements of it were taken at locations 721 to 724, 726 and 727, and at location 725, in sec. 31 of the township to the north. Detailed sections (Pl. IX) show that the bed ranges from 2 to 4 feet in thickness. No trace of this bed was found along the valley in the eastern part of the township. At location 724, in the SW. ¼ sec. 4, where the bed measures 2 feet 2 inches, a small amount of lignite has been taken out by the residents near by. At location 726, in the NW. ¼ sec. 6, there is an abandoned strip pit.

About 200 feet above this bed a second bed outcrops underneath the tops of the highest hills and buttes through the middle and

western parts of the township. At location 728, in a small butte in sec. 13, 2 feet of lignite is exposed, and the bed is of about the same thickness in the buttes in the center of the township, but along the western tiers of sections it is much thicker. A section measured at location 717, in the SE. ¼ SW. ¼ sec. 18, shows that the bed is there 5 feet 7 inches thick. However, on the south side of this small hill, in sec. 19, the bed is less than 2 feet thick. It seems possible that one of the beds at the small prospect at location 705, in the NW. ¼ sec. 31, is on the same bed of lignite. At this locality the upper bench is 2 feet 6 inches thick; the lower bench was covered by the dump from the upper bench, but was reported to be 3 feet thick. At location 707, near the east line of sec. 24, T. 19 N., R. 8 E., near the "big stone cairn," 2 feet of lignite was measured, and at location 708, in sec. 25, there is 2 feet 10 inches of fair lignite in the same bed. The variation in thickness of this bed is shown graphically by secs. 705, 706, 717 to 720, and 728, Plate IX.

A third bed of lignite occurs nearly 100 feet above the bed just described, and small areas underlain by it remain in the southwest corner of the township. Measurements show that the bed ranges from 3 feet 4 inches to 6 feet in thickness. Detailed sections at locations 713 to 716, 702, 703, and 704 are given on Plate IX. In a small gully in secs. 19, 20, 29, and 30 and also in the east side of sec. 20 measurements of lignite were made, but the beds could not be correlated. Sections measured at locations 709, 710, and 712 are shown on Plate IX.

T. 20 N., R. 9 E.

T. 20 N., R. 9 E., is drained directly or indirectly by the South Fork of Grand River, which meanders in a general easterly direction through the south tier of sections. The river is one of the few perennial streams of this field, and at flood times is joined by several small streams from the northwest. It drains all but the northeast corner of the township, which is drained by Big Nasty Creek. Fairly good water is obtained in wells at depths of 50 to 200 feet.

There is a total relief of about 500 feet. The highest points are in the extreme northwest corner and have an elevation of about 3,000 feet above sea level. The east side of the township is rolling and uneven, but the northwestern and middle parts are decidedly rugged. Between the several small streams which meander through narrow valleys approximately parallel to the strike of the rocks there are high, narrow, rugged divides, along the sides of which the rocks are well exposed. The valley of Grand River is about 2 miles wide, but is too sandy for attractive farm land.

The roughness of the surface makes successful farming in this township an impossibility, except in a few small areas along the stream valleys. The Olsen ranch, in sec. 21, the Leadbeater, in sec.

36, and the Wagner, in sec. 7, are small stock ranches and constitute the principal permanent settlement. Homesteaders have taken up the more favorable tracts of land and are attempting to raise flax, wheat, and other small grains. Wagon roads for the most part follow the old trails, which were laid out in the early days along the easiest lines of travel.

Aside from the recent deposits along the south fork of Grand River and the main creeks, the rocks belong to the Lance formation. About 400 feet of strata are exposed, and so far as noted they are essentially horizontal, having a northeastward dip that does not exceed 15 or 20 feet to the mile.

The lower 50 or 100 feet of rocks exposed along South Fork of Grand River are somewhat more shaly than the upper beds. They are gray, drab, and in places brown in color, and here and there they contain a small lignite bed of no value. The upper beds, which are called the Ludlow lignitic member of the Lance, are more sandy and lighter in color, some of them being almost white and others buff or yellow. No fossils were collected from any of the rocks in this township, but their age is determined by correlation with rocks in adjacent townships.

Several beds of lignite outcrop in this township. Some are of considerable thickness, but others are thin and lenticular. The more valuable beds were mapped in the field in considerable detail, and their outcrops are shown on Plate I. In general, the beds are limited to the middle and northwest corner of the township. The lowest bed mapped is at the base of the Ludlow member and is the same as the lowest bed mapped in T. 20 N., R. 8 E.; in T. 19 N., R. 9 E.; and in sec. 32, T. 20 N., R. 10 E., and possibly the same as the bed mapped east of Glendo post office, at the junction of Big Nasty Creek and the South Fork of Grand River. Only two measurements of the bed were taken in this township—one at location 729, in the NE. ¼ sec. 32, (see Pl. IX), where only 10 inches of lignite is exposed, with an 8-inch bed 6 feet below, and the other at location 725, in sec. 31, where the bed is 3 feet 8 inches thick.

About 100 feet above this bed is a second lignite. Owing to the fact that in many places outcrops are separated by grassy slopes, there is some doubt as to the accuracy of correlation, but exposures at locations 739, 741, and 743 to 747 are thought to be on this bed. Details of these measurements are given on Plate IX. At location 745, in sec. 27, a small mine has been opened on this bed. The bed ranges in thickness from 11 inches at location 747 to 4 feet 5 inches at location 745, and only here and there is it of even local importance. At location 742 in section 14 a thin bed is exposed, but its correlation with other beds was not determined.

About 50 feet above this bed is a third, which was measured at locations 730, 740, 732 to 738, 769, 774, and 776. (See Pl. IX.) In

thickness it ranges from 6 inches at location 736, in sec. 21, to 5 feet 4 inches at location 737, in sec. 22. At location 776, in sec. 5, the bed is only 8 inches thick, and at many other places it holds about the same thickness. Its elevation is from 2,770 to 2,780 feet above sea level.

About 20 or 30 feet above it, in sec. 18 and vicinity, occurs a fourth bed which ranges in thickness from 6 inches along the road in the SE. ¼ NE. ¼ sec. 18 to 1 foot 6 inches at location 731.

About 40 or 50 feet above the thin bed last mentioned is the only valuable bed in the township, and its outcrop was traced in detail. The measurements at locations 750 to 758, 760 to 765, 767 and 768, and 770 to 773 (shown in detail on Pl. IX) are considered to be on this bed. Its altitude is from 2,800 to 2,840 feet, the northeastern exposures being the lower. It is possibly the same bed as the Widow Clark bed in T. 21 N., R. 7 E. At the Olson mine (location 753), in the SW. ¼ SE. ¼ sec. 17, the bed is 11 feet 4 inches thick, and at the Newcomb mine (location 762), in the SW. ¼ SW. ¼ sec. 10, it contains 10 feet 8 inches of first-class lignite. A sample was taken at the Newcomb mine for analysis (No. 15062), which was made by the Bureau of Mines. Although in the main this bed is persistent it varies decidedly from place to place. For instance, at location 764, in the NW. ¼ NE. ¼ sec. 8, only 1½ miles west of the Newcomb mine, the bed is but 2 feet 6 inches thick and is badly split by shale. In the township to the north the bed thins to about 3 feet. Its quality, as shown by the analysis, is good, and field inspection at other places revealed little impurity. A considerable part of the northwest corner and middle of the township is underlain by this lignite, with cover ranging from a few feet to about 150 feet.

The bed at location 759, in sec. 23, is shown graphically on Plate IX. It lies above the Widow Clark bed.

T. 21 N., R. 9 E.

The valley of Big Nasty Creek, which crosses T. 21 N., R. 9 E., from northwest to southeast, is fairly broad and open, as is that of a large stream leading southeastward from the Lodgepole Buttes and joining Big Nasty Creek in sec. 35. Both of these streams follow markedly meandering courses. The southwest corner of the township is very rough and of a somewhat badland character. The northwest corner is high and mesa-like and is a part of the upland which surrounds the Lodgepole Buttes. The remaining portions are rough, broken, and grass-covered. The total relief is in the neighborhood of 400 feet, the highest points being in sec. 11, at 3,000 feet above sea level, and in the northwest corner of sec. 6, at 2,980 feet.

Nearly every desirable quarter section has been filed upon by homesteaders. A small tract of land has been irrigated on the Shirley ranch, in sec. 9, and a fine crop of wheat was raised there in

1912. The Howard ranch, one of the oldest in this vicinity, is in sec. 19. Along Big Nasty Creek and its large tributary in the middle of the township there are small areas of irrigable land, but the supply of water is rather meager. Watson post office, in sec. 14, receives mail from Reeder, N. Dak.

The total thickness of rock exposed in this township is about 400 feet. The lower 50 or 75 feet of strata exposed along the banks of Big Nasty Creek consist of dark-colored shale, with beds of brownish sandstone and thin beds of lignite. They carry characteristic ferruginous nodules, which, after the rocks are disintegrated, remain on the weathered surface as brownish or reddish rounded masses. The soil resulting from the breaking down of this shale is gumbo-like and supports but little vegetation.

The succeeding rocks are more sandy and contain a number of lignite beds. These rocks, which cover the southwestern part of the township, are classed as the Ludlow lignitic member of the Lance formation. Rocks evidently belonging to the Lance formation exposed in the northeastern part of the township and occupying nearly the same stratigraphic position as those of the Ludlow member are placed in the Cannonball marine member of the Lance. The evidence for this correlation is a bed of oysters, *Ostrea glabra*, found in sec. 14. These fossils occur at about the same horizon as the marine fossils collected in T. 23 N., R. 9 E. The rocks consist of shale and sandstone. The division between the marine and lignitic members of the Lance along Big Nasty and Shirley creeks is arbitrarily drawn, because it was not mapped in the field.

The upper 75 feet of strata are classed as the Fort Union formation. They are light-colored and are mostly fine-grained sandstone, with interbedded soft shale and thin lenses of limestone. The sandstone is locally ripple-marked and somewhat cross-bedded. The limestone is light buff or brownish yellow on the oxidized surface and drab to bluish gray on the unaltered surface. In sec. 11 there are a great number of quartzite bowlders, which are derived from a thin stratum of siliceous rock occurring about 150 feet above the base of the formation. The nearest locality where such material is found in place is Anarchist Butte, in sec. 34, T. 22 N., R. 9 E., where the stratum has an altitude of 3,050 feet. The bowlders do not disintegrate readily, hence they remain scattered over the surface after the inclosing strata have been washed away.

Alluvium occurs along the two main creeks in an area about one-fourth to one-half mile in width.

The strata of this area are essentially horizontal. Altitudes on beds at three different horizons in northeastern Harding County show that the rocks in this general region have a dip to the northeast of about 20 feet to the mile.

Two valuable beds of lignite crop out in this township. The lower one is possibly the same as the Widow Clark bed of T. 21 N., Rs. 7 and 8 E. Its outcrop was traced with considerable difficulty, owing to the grass-covered slopes, but several measurements of the bed were obtained. On the north side of Big Nasty Creek at locations 784 to 786, in secs. 19 and 20, it is more than 3 feet thick. No evidence of its presence was detected in the area east of the northwest corner of sec. 9, although Mr. Korsca, at Watson, in sec. 14, reports having struck in his well about 3 feet of lignite, which may be the same bed. A small outlier of this bed occurs in secs. 27 and 21, and a measurement at location 783 (see Pl. IX) shows the bed to be 3 feet 10 inches thick. Five sections exposed at locations 642, 643, 777, 779, 780, and 781, in secs. 31 and 32, are supposed to be on this bed. Its thickness ranges from 2 feet 2 inches at location 779 to 4 feet 8 inches at location 642. At location 781 the bed is represented by carbonaceous shale. Further detailed information is given on Plate IX. In a narrow draw in the western part of sec. 31 (locations 642 and 643) there are two small strip pits on the bed, from which lignite has been mined by the near-by inhabitants.

About 50 feet above this bed is a second bed, which at locations 640 and 778 shows the detail given on Plate IX. At location 660A, in the SW. ¼ sec. 18, this bed is 2 feet 1 inch thick. In the SW. ¼ sec. 31 red rock possibly formed by the burning of the Giannonatti bed is exposed near the top of a hill, but no lignite is present. Along the bank of Big Nasty Creek at location 782, in sec. 28, occurs the lowest bed of lignite examined in this township. It is 2 feet thick and has been prospected for a fuel supply for local use.

T. 22 N., R. 9 E.

From the high grassy divide which crosses T. 22 N., R. 9 E., in a westerly direction, the surface slopes gradually to the North Fork of Grand River on the north and Big Nasty Creek on the south. The most imposing topographic feature of this part of the field consists of the Lodgepole Buttes, three rocky prominences, rising about 200 feet above the surrounding country, or 3,222 feet above sea level, in secs. 19 and 20 of this township and secs. 24 and 25 of the township to the west. The buttes are capped by a massive sandstone that protects the underlying strata from erosion. Another prominent topographic feature is Anarchist Butte, in secs. 33 and 34.

Although nearly every tillable section of land has been taken by homesteaders, there are now only a few settlers who are meeting with success in raising crops. A large number of tracts that were cultivated for a time are now overrun with weeds and Russian thistles, although unbroken meadow lands still produce an abundance of prairie grass. The average annual rainfall is not more than 15

inches, and there is little or no water for irrigation, so that the future success of farming depends on the development and use of adequate dry-farming methods. Good springs issue from the north and south sides of the Lodgepole Buttes. Aside from the springs the residents depend on wells, usually less than 200 feet deep, for water supply. Wagon roads can easily be built along section lines, and those few which still follow the old trails will ultimately be shifted to the section lines.

There are 420 feet of rocks exposed in this township, the lower 100 feet of which belong to the Ludlow lignitic member of the Lance formation and consist of interbedded shale, sandstone, and lignite. This member is exposed along the north side of the township, but erosion has not cut deeply enough in the south side to reveal its presence. Interbedded with the Ludlow member and below the Fort Union formation there is a thin series of strata assigned to the Cannonball marine member of the Lance. Although this member contains marine fossils in adjacent areas, none were found in this township, and as the rocks are similar lithologically to those of the lignitic member the boundary between these members is drawn arbitrarily.

The Fort Union formation overlies the Lance and is exposed in almost all parts of the township, but its maximum thickness (320 feet) is shown only in the Lodgepole Buttes. The lower part of the formation consists of interbedded buff to yellow shale and sandstone, with here and there a thin bed of limestone. The resistance to erosion of the thin indurated sandstones and limestones has produced the rather abrupt slopes leading from the creek bottoms to the upland. The quartzite of the Fort Union occurs in place about 95 feet below the top of Anarchist Butte, and the numerous quartzite bowlders which are scattered over the township, particularly along the south side, are derived from this stratum. In some places these bowlders are so thick as to interfere materially with the cultivation of the soil. The massive coarse-grained brownish sandstone that caps the Lodgepole and Anarchist buttes is from 50 to 75 feet thick and is stratigraphically the uppermost Fort Union rock in the State. The rocks of the Fort Union formation are in general lighter colored and more regularly bedded than those of the Lance.

A northeastward dip of the formations in this township amounting to about 20 feet in a mile is shown by the elevations determined on the upland area, which apparently is capped by the same series of sandstones and limestones.

The lowest bed of lignite that was found cropping out in this area has been mined at location 791 (see Pl. IX), in sec. 4.

At location 790, in sec. 4, the bed is 2 feet thick. This lignite bed is probably the same as the one mapped in sec. 36, T. 23 N.,

R. 9 E., and in the vicinity of Bloom. It is possibly the same as that mapped on the north side of the township to the south, but of this there is no direct evidence.

A second lignite bed underlies the Lodgepole Buttes, and at location 788, in sec. 19, where its thickness is 4 feet, a small mine has been opened on it. In a draw near the northwest quarter corner of sec. 30 a second mine has been opened on a bed of lignite possibly the same as the one on the north slope of the buttes. The mine when visited was so badly caved that no section was obtained. The altitude of the bed as determined on the north slope of the buttes is 3,020 feet. The bed is possibly the same as that mapped near Lodgepole post office.

T. 23 N., R. 9 E.

The drainage of T. 23 N., R. 9 E., goes into the North Fork of Grand River and its small tributaries. The river in very dry seasons is intermittent, although classed as a perennial stream. The total relief of the surface is 300 feet, and the highest determined point is along the south township line in sec. 32. The river at its lowest point in sec. 24 has an altitude of 2,600 feet. A considerable portion of the upland consists of broad, flat stretches of treeless, grass-covered country or cultivated fields. The uplands have a rather precipitous boundary, caused by the ledges of sandstone and limestone, which resist erosion. The open valley of the North Fork of Grand River is about a mile in width. The physiographic expression of this area is one of maturity, the drainage being well established, the streams meandering over their valley floors, the uplands being almost entirely dissected, and no undrained areas remaining.

Practically all the land has been taken up in homesteads and fairly good crops of wheat and flax are grown. If the precipitation were greater and more evenly distributed over the year, the soil would be productive and the country prosperous. Bloom post office is in sec. 24, along the State line.

The lower 75 to 100 feet of rocks exposed along the North Fork of Grand River are composed of shale, lignite, calcareous sandstone, and sandy limestone. The part including two lignite beds is nonmarine, but the part below the lowest exposed lignite is marine at least in places and that above the upper lignite for a few feet is also marine. Marine Cretaceous fossils collected in secs. 24 and 36 indicate transgression of the sea at the close of Lance time. The marine beds are included in the Cannonball marine member of the Lance, and the nonmarine beds in the Ludlow lignitic member.

A few feet of the Fort Union formation caps the interstream areas. The rocks are chiefly thin beds of decidedly ripple-marked, somewhat resistant sandstone, and thin lenses of limestone. The limestone is

light buff to yellow on the oxidized surface, but when broken open the fresh surface is drab or bluish. It has a conchoidal fracture and is very dense in texture.

As determined from the altitudes of the lignite beds and the level stretches of upland, which are apparently capped by the same ledges of sandstone and limestone, the rocks have a slight eastward dip of about 20 feet to the mile.

Two beds of lignite crop out in the township. The lower one is locally known as the Billy Green bed. At location 797 (see Pl. IX), near the old Green ranch, both beds were measured.

East of Bloom, at location 793, the lignite is only 1 foot thick, only one of the lower two benches in the previous section being found. The bed was traced to location 792, in the SE. ¼ sec. 21, where the section given in Plate IX was measured.

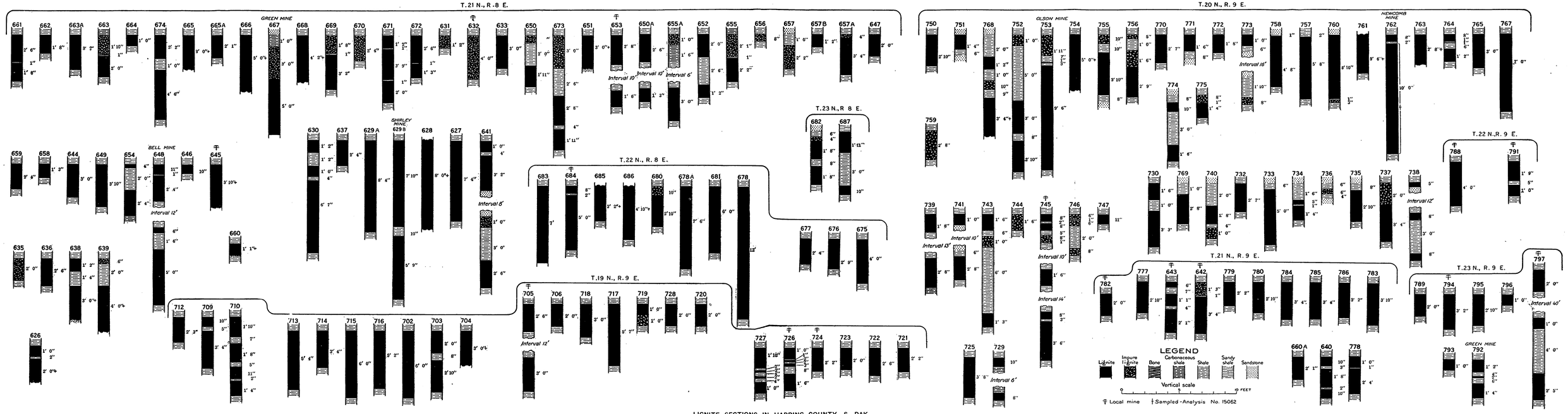
A few loads of lignite have been mined at this place, but the bed is badly split by shale partings and on the whole seems to be of poor quality. The general low grade of the lignite is shown by the fact that the people living in this immediate vicinity would rather, when they can afford it, drive to the railroad and buy Roundup or Hocking Valley coal. The correlation of the Billy Green bed with beds in adjacent townships was not attempted and probably can not be accurately made. However, a bed that crops out in T. 23 N., R. 10 E., is apparently the same.

About 40 to 50 feet above the Billy Green bed occurs the second bed of lignite, on which measurements were made at locations 789, 797, 794, 795, 796. (See Pl. IX.) The bed is thickest in sec. 36, where at a small mine (location 794), 3 feet 2 inches of very good lignite is exposed. At location 795, at a spring, the bed is 2 feet 10 inches thick. The bed was mapped about half a mile northward from location 795, but the best measurement obtainable was 1 foot of lignite at location 796. A thickness of 4 feet of lignite was reported to have been found in a well in the NW. ¼ sec. 6, T. 22 N., R. 10 E., at a depth between 40 and 60 feet. This is probably the same bed of lignite. This bed is exposed at location 793, in the middle of sec. 24, but is only a few inches thick. At all other places in this township where the bed was measured it is less than 2 feet thick and its outcrop was not mapped in detail. In the western part of the township no evidence of this lignite or even a lower bed was found.

T. 16 N., R. 10 E.

A gently rolling grass-covered prairie constitutes the surface of a large part of T. 16 N., R. 10 E. The small town of Vernal, in sec. 7, is surrounded by a large number of successful farms.

The surface rocks belong to the Lance formation, the Ludlow lignitic member occupying a small area along the divide north of



LIGNITE SECTIONS IN HARDING COUNTY, S. DAK.

In area examined by C. J. Hares.

Antelope Creek. From such data as the few exposures of rock afford, it is evident that the beds dip slightly northeastward. So far as is known to the writers, no bed of lignite is exposed in the township, and the underlying rocks are believed not to contain lignite in this part of the field.

T. 17 N., R. 10 E.

Rabbit Creek, which crosses T. 17 N., R. 10 E., from west to east, occupies a rather broad valley, on the south side of which the land rises rapidly to a high divide in the southern part of the township. Sorum, in sec. 7, is a small but prosperous town on the surveyed line of a branch of the Chicago, Milwaukee & St. Paul Railway and forms the trading center for a large farming community.

The surface rocks belong to the Lance formation. The Ludlow lignitic member of the Lance is exposed in the high divide in the southern part of the township, where it has a maximum thickness of about 200 feet. The lower sandstones of the member also cap the divides north of the creek. The formation dips gently northeast.

Although the gently rolling surface of this township is in most places grass-covered, lignite beds are exposed at a number of places. The thickest bed crops out near the top of a small hill at location 799, in sec. 28 (see Pl. XI), where a small mine has been opened and a few loads of lignite have been removed. Although the bed has a thickness of 3½ feet at this locality, there is hardly sufficient cover anywhere to prevent the weathering of the lignite, and consequently it is not workable except for local use. The Knudsen mine, at location 811, in sec. 2 (Pl. V, *A*, p. 44), is the only place in the township where lignite has been mined in a commercial way. The mine was opened by Andrew H. Knudsen in 1910 and was worked by stripping the overburden, but at the time of examination, in August, 1911, several hundred feet of narrow entries had been driven close together, leaving no space for rooms. It is reported that during the winter of 1910–11 more than 100 wagon loads of lignite, or approximately 200 tons, was sold to the farmers of the surrounding country. The following section of the bed was measured near the end of the workings, about 150 feet from the opening, where a sample of the lignite was taken for analysis (No. 12454, p. 42):

Section in Knudsen mine, at location 811, sec. 2, T. 17 N., R. 10 E.

	Ft.	in.
Shale, sandy.		
Lignite, fair (included in sample)		10
Lignite (included in sample)	1	9
Shale, brown		4
Clay, lignite, bony		7
Total section	3	6
Total lignite	3	2

At location 810, in sec. 2, the same bed of lignite as the one mined at the Knudsen mine is only 2 feet 6 inches thick.

Thinner lignite beds are exposed at a number of localities in the township, but no attempt was made to correlate them. The locations where measurements were made are shown on Plate II (in pocket), and the following sections indicate the character of the beds:

Sections of lignite beds in T. 17 N., R. 10 E.

[In addition to those shown on Pl. XI.]

No. on Pl. II.	Location.	Section.	Ft.	in.
798	SE. ¼ sec. 29...	Shale, sandy.		
		Shale, brown.....	2	0
		Lignite.....		6
		Shale, brown...	1	3
		Lignite, poor...	1	8
		Shale, brown.		
		Total section.	5	5
		Total lignite..	2	2
800	SE. ¼ sec. 30 ..	Clay, sandy.		
		Lignite.....		6
		Shale.....	2	6
		Lignite, poor...	2	6
		Shale, brown.		
		Total section.	5	6
		Total lignite..	3	0
801	NW. ¼ sec. 28 .	Soil.		
		Lignite.....	1	6+
		Base not exposed.		
802	SW. ¼ sec. 19..	Clay, sandy.		
		Shale, brown.....	1	6
		Lignite.....	1	6
		Shale, brown.		
		Total section.	3	0
		Total lignite..	1	6
803	NW. ¼ sec. 19..	Sandstone, gray.		
		Lignite.....	1	1
		Shale.		
804	SE. ¼ sec. 18...	Sandstone, light gray.....	4	0
		Shale, brown.....		3
		Lignite.....		11
		Shale, brown...		6
		Lignite.....		6
		Shale, brown...		2
		Lignite.....	1	6
		Shale, brown.		
		Total section.	7	10
		Total lignite..	2	11
805	NE. ¼ sec. 18..	Shale.		
		Lignite.....		3
		Shale.....		8
		Lignite.....		6
		Shale.....		1
		Lignite.....		11
		Interval, about.....	25	
		Shale, gray.....		8
		Lignite.....	1	6
		Shale, brown.		
		Total section.	29	7
		Total lignite..	3	2
806	NE. ¼ sec. 18..	Shale, brown, sandy.		
		Lignite.....		9
		Shale.....		8
		Lignite.....		2
		Shale.....		2
		Lignite.....	1	1
		Shale, brown...	1	9
		Lignite.....		7
		Shale, brown.		
		Total section.	5	2
		Total lignite..	2	7
807	NW. ¼ sec. 18 .	Sandstone.		
		Shale, brown.....		3
		Lignite.....	2	0
		Shale, brown.		
		Total section.	2	3
		Total lignite..	2	0
808	NW. ¼ sec. 18..	Soil.		
		Lignite.....	1	9
		Shale, brown.		
809	NW. ¼ sec. 3'. .	Lignite, about.....	2	
812	SW. ¼ sec. 1...	Shale.		
		Lignite.....		6
		Shale, brown.....	3	0
		Lignite.....	1	7
		Shale, brown.		
		Total section.	5	1
		Total lignite..	2	1

T. 18 N., R. 10 E.

The surface of T. 18 N., R. 10 E., is a rolling grass-covered prairie, parts of which have been broken for cultivation in the last few years. By far the larger part of the township is comparatively level and forms good farm land, the maximum difference in altitude between the valley in sec. 33 and the top of White Hill, in sec. 4, being only about 200 feet. A large number of farmers have settled in this part of the field.

A small area of the lower part of the Lance formation is exposed in secs. 31, 32, and 33, and the Ludlow lignitic member of the Lance, exposed south of the South Fork of Grand River, reaches its maximum thickness (about 325 feet) in the divide along the northern edge of the township. White Hill, in sec. 4, is capped by about 50 feet of the White River formation and rises as a prominent landmark above the general level of the meadow land.

A single bed of lignite was measured at location 813, in sec. 20, where it is 2 feet 8 inches thick and lies between beds of brown shale.

Part of the land in the southeast corner of the township is probably underlain by the lignite bed worked at the Knudsen mine, in sec. 2, T. 17 N., R. 10 E., but as this bed is less than 3 feet thick at all points along its outcrop, it is thought to be of little commercial importance. The bed of lignite mined at the Jones mine, at location 824, in sec. 35, T. 19 N., R. 10 E., where it is about 5 feet thick (see Pl. XI), in all probability underlies a part of the northeast quarter of this township. A lignite bed 1 foot 6 inches thick, reported at a depth of 30 feet in a well at location 814, in sec. 13, may be at the same bed as that at the Jones mine.

T. 19 N., R. 10 E.

T. 19 N., R. 10 E., lies in the area known locally as The Breaks and, as that name indicates, the surface is deeply dissected, many of the small streams tributary to the South Fork of Grand River occupying narrow, steep-sided valleys more than 100 feet deep. Owing to this fact very little has been accomplished in attempts at farming in the township. There is a difference in altitude of about 300 feet between the valley of the South Fork of Grand River on the north and the Meadow flat in the southern part of the township.

The surface rocks belong to the Ludlow lignitic member of the Lance formation, nearly the entire thickness of which is represented. From data collected along the outcrops of lignite beds the rocks appear to dip gently to the northeast.

Several more or less valuable beds of lignite outcrop in the rough area north of the Meadow. The best and stratigraphically the highest bed was traced from a point near the west edge of the township eastward into T. 19 N., R. 11 E., and has a thickness varying from 1 foot 8 inches at location 815, in sec. 32, to 6 feet 1 inch at a small mine at location 821, in sec. 27. Farther east the bed is thinner, so that at location 895, in sec. 20, T. 19 N., R. 11 E., it is represented by only 2 feet of lignite. Two mines are located on this bed in the township; a small opening at location 821, where after stripping off the overlying rock the operators removed several loads of lignite; and the Jones mine (Pl. V, *B*, p. 44), at location 824, in sec. 35, which is worked from a number of drift openings. The bed

at the Jones mine is 5 feet 4 inches thick (see Pl. XI) and is overlain by 75 to 100 feet of cover. In mining, the upper bench of lignite, 1 foot 2 inches thick, is left as roof. In August, 1911, the mine workings consisted of a main entry about 200 feet long and numerous rooms on each side. Before the present system of mining was adopted seven parallel drifts were run into the side of the hill for distances of nearly 100 feet, but all except the one now used for a main entry were abandoned in 1909. The equipments of the mine included two cars, platform scales, and a small blacksmith shop. One man was working in August, 1911, and several wagon loads of lignite were sold daily. The output for 1910, which was sold to the farmers near by at $2.50 a ton at the mine, was 925 tons. The lignite as it comes from the mine is hard, brown, and woody, but it weathers too rapidly to stock successfully. Analysis 12453 (p. 42) was made on a fresh sample and represents the general character of the lignite in this mine. All the measurements taken on this bed (sections 815 to 828, 830, and 852) are shown graphically on Plate XI.

About 45 feet below the Jones bed lies a thin bed of lignite, which, probably because of its proximity to the more valuable bed above, has never been prospected. It varies in thickness, reaching a maximum of 2 feet 9½ inches. The variation is shown by the following sections:

Sections of lignite bed, 45 feet below the Jones bed in T. 19 N., R. 10 E.

No. on Pl. II.	Location.	Section.	Ft.	in.
834	SE. ¼ sec. 29...	Shale, brown.		
		Lignite.....	1	3
		Shale, brown.		
835	NW. ¼ sec. 28..	Shale, brown.		
		Lignite.....	1	5
		Shale, brown.		
836	SW. ¼ sec. 21..	Sandstone, yellow.		
		Lignite.....	1	11
		Shale, brown.		
837	SW. ¼ sec. 22..	Shale, brown.		
		Lignite.....	1	6
		Shale, brown...		1½
		Lignite.....	1	2
		Shale, brown.		
		Total section.	2	9½
		Total lignite..	2	8
838	SW. ¼ sec. 22..	Shale, brown.		
		Lignite.....	1	1
		Shale brown...		3
		Lignite.....	1	0
		Shale, brown.		
		Total section.	2	4
		Total lignite.	2	1
839	SE. ¼ sec. 22...	Shale.		
		Lignite.....	2	4
		Interval.....	22	0
		Lignite.....	2	0
		Shale, brown.		
		Total section.	26	4
		Total lignite..	4	4
840	NE. ¼ sec. 22...	Shale, blue.		
		Lignite.....		10
		Shale, brown...		3½
		Lignite	1	8
		Shale, brown.		
		Total section.	2	9½
		Total lignite..	2	6

A small strip mine has been opened at location No. 844, in sec. 23, on a bed of lignite 1 foot 9 inches thick, which occurs at a still lower horizon. Only a small amount of fuel had been mined previous to August, 1911.

Beds of lignite, either thin or of local extent, so that they were not correlated, except in a few places, are exposed at various localities in the township. Sections measured on these beds are as follows:

Sections of thin lignite beds in T. 19 N., R. 10 E.

[Not shown on Pl. XI or given above in text.]

No. on Pl. II.	Location.	Section.	Ft.	in.
831	SE. ¼ sec. 29...	Soil.		
		Lignite.....	1	9
		Shale, brown.		
832	SE. ¼ sec. 29...	Shale, brown.		
		Lignite.....	1	0
		Shale, brown.		
833	SW. ¼ sec. 28...	Shale, gray.		
		Lignite.....	1	4
		Shale, brown.		
840	NE. ¼ sec. 22...	Shale, bluish yellow.		
		Lignite.....		10
		Shale, brown...		3½
		Lignite.....	1	8
		Shale, brown.		
		Total section.	2	9½
		Total lignite..	2	6
841	NW. ¼ sec. 16..	Shale, light brown.		
		Lignite.....	1	9
		Shale, carbonaceous		5
		Shale, light brown.		
		Total section.	2	2
		Total lignite..	1	9
842	SE. ¼ sec. 4....	Soil.....	2	
		Shale.....		8
		Lignite.....	1	9
		Interval.....	13	
		Lignite.....		8
		Shale, brown.		
		Total section.	18	1
		Total lignite..	2	5
843	NW. ¼ sec. 23..	Shale, brown.		
		Lignite.....	1	9
		Shale, brown.		
845	NW. ¼ sec. 24..	Soil.....	3	0
		Shale, brown.....		9
		Lignite.....	1	4
		Shale, brown.		
		Total section.	5	1
		Total lignite..	1	4
846	NE. ¼ sec. 14...	Shale, light brown.		
		Lignite.....	1	10
		Shale, dark brown.		
847	SE. ¼ sec. 14...	Shale, brown, sandy.		
		Lignite.....	1	10
		Shale, brown, lignitic.		
848	NE. ¼ sec. 12...	Shale, brown.		
		Lignite.....	2	9
		Shale, yellowish brown.		
849	SE. ¼ sec. 1....	Soil.....	3	0
		Lignite.....	1	4
		Shale, brown.		
		Total section.	4	4
		Total lignite..	1	4
850	SW. ¼ sec. 1...	Clay.		
		Lignite.....	2	6
851	SW. ¼ sec. 1....	Sandstone.....	3	0
		Shale, brown.....		8
		Lignite.....		3
		Shale, brown...		9
		Lignite.....		1
		Sandstone.....		3
		Shale, brown...		5
		Sandstone.....		5
		Shale, brown...		2
		Lignite.....	1	9
		Shale, brown.		
		Total section.	7	9
		Total lignite..	2	1
853	NE. ¼ sec. 14...	Sandstone.		
		Shale, brown.....		8
		Lignite.....	2	0
		Shale, brown.		
		Total section.	2	8
		Total lignite..	2	0

Part of the northeast quarter of this township is probably underlain by a bed of lignite that crops out along the South Fork of Grand River in secs. 26 and 35, T. 20 N., R. 10 E., and is described below.

T. 20 N., R. 10 E.

The South Fork of Grand River crosses the southern part of T. 20 N., R. 10 E., in a rather broad valley along which are several small areas of sand dunes. Big Nasty Creek, one of the perennial streams of the region, enters the township from the northwest and flows in a meandering course, joining the South Fork in sec. 24. In the river valley and in the valley of Big Nasty Creek there are

numerous tracts of cultivated land, but the upland area is rough and grass covered. Rock exposures are few.

The Ludlow lignitic member of the Lance formation, dipping gently eastward, constitutes the surface rock of nearly the entire township. In parts of secs. 1 and 2 the surface is formed by rocks of the Cannonball marine member, and along the South Fork of Grand River there is a narrow area, in which the lower part of the Lance formation is exposed. In most places, however, the lower Lance beds are covered by alluvium.

The lignite bed occurring at the base of the Ludlow member is the only one which has attracted attention in this township. In secs. 26 and 35 considerable prospecting has been done and some lignite has been removed by the farmers living in the vicinity. The bed, which is exposed in the south bank of the river, is comparatively uniform in thickness and contains about 3 feet 10 inches of good lignite, as shown by sections 858, 859, and 860, Plate XI. At locations 861 (see Pl. X), in sec. 23, near the mouth of Big Nasty Creek, a bed having a thickness of 1 foot 10 inches is supposed to be the same. At location 855, in sec. 32, there is a bed 1 foot 8 inches thick at the base of the Ludlow lignitic member of the Lance, which may be the same as the bed described above or it may be a separate lens. To the east, beyond the limits of the township, the bed is not exposed, but in sec. 28, T. 20 N., R. 11 E., there is apparently another lens of lignite at about the same horizon.

Several thin beds in the Ludlow member are exposed at different localities in the township and are represented by the following sections. The exact correlation of the beds is impossible because of the grass-covered surface between the exposures:

Sections of thin lignite beds in T. 20 N., R. 10 E.

[Not shown on Pls. X and XI.]

No. on Pl. II.	Location.	Section.	Ft.	in.	No. on Pl. II.	Location.	Section.	Ft.	in.
854	SW. ¼ sec. 36..	Shale, brown.			862	SW. ¼ sec. 2...	Lignite.....	2	2
		Lignite.....	2	1	863	NW. ¼ sec. 2..	Shale, gray.		
		Shale, black.					Lignite.....	2	2
856	NW. ¼ sec. 29.	Shale, brown.					Shale, brown.		
		Lignite.....	2	1	864	NW. ¼ sec. 2..	Shale, sandy.		
		Shale, brown.					Lignite.....	2	1
857	SE. ¼ sec. 19...	Clay.					Shale.		
		Lignite, poor...	1	4					
		Shale, brown.							

T. 21 N., R. 10 E.

The divide between the North and South forks of Grand River, consisting of a nearly flat plateau, crosses the northeastern part of

T. 21 N., R. 10 E., and is separated by a series of steep scarps from the lower country in the southern part.

The rocks that outcrop in the township belong to the Fort Union formation and to the Ludlow lignitic and Cannonball marine members of the Lance formation. About 150 feet of the lower part of the Fort Union crops out in the northeastern part of the township. With the exception of the upper 30 or 40 feet on Flat Top Butte, in sec. 10, these rocks are concealed by the mantle of soil. The topography and the character of the soil, however, indicate that sandstone is the principal rock. The Lance formation is represented along the south side of the plateau by about 250 feet of sandstone and shale, but the rocks are so deeply covered by soil that no definite conception of them could be obtained. It is probable that the upper 25 to 50 feet of this formation belongs to the Cannonball marine member and the remainder to the Ludlow lignitic member.

Lignite beds belonging to the Ludlow member and reaching a maximum thickness of 2 feet 10 inches are exposed in secs. 30, 33, and 34. Lignite near the top of the Ludlow member was also said to have been found in two wells in sec. 17. The sections of the beds at these places are as follows:

Sections of lignite beds in the Ludlow lignitic member of the Lance formation in T. 21 N., R. 10 E.

Location 865. SW. ¼ sec. 34.

	Ft.	in.
Shale, gray.		
Lignite, low grade	2	4
Shale, brown.		

Location 866. NW. ¼ sec. 33.

	Ft.	in.
Shale, light brown, fissile.		
Lignite, weathered	2	6
Lignite, low grade		4
Shale, light brown.		
Total lignite	2	10

Location 867. SE. ¼ sec. 30.

	Ft.	in.
Shale, gray.		
Shale, carbonaceous, with thin lenses of lignite	2	10
Shale, light brown		½
Lignite		6
Shale, light brown.		
Total section	3	4½
Total lignite		6

Location 868. SE. ¼ sec. 30.

	Ft.	in.
Shale, gray.		
Shale, carbonaceous, grading into bone and thin streaks of lignite	1	3
Lignite		7
Shale, light brown		½
Lignite		6½
Shale.		
Total section	2	5
Total lignite	1	1½

Location 869. SE. ¼ sec. 17.

Well reported to have passed through about 5 feet of weathered lignite at a depth of 30 feet.

Location 870. SE. ¼ sec. 17.

Well reported to have passed through 2 feet of weathered lignite at a depth of 30 feet.

The outcrops could be traced for only short distances, and the beds recorded above could not be definitely correlated.

A bed of lignite in the Fort Union crops out near the top of Flat Top Butte, in sec. 10, and is correlated with the valuable bed near Lodgepole, in T. 21 N., R. 12 E. At the only place suitable for

examination (location 871) the bed is 2 feet 2 inches thick but considerably burned. About 20 feet below the lignite there is a persistent layer of very hard quartzitic rock, remnants of which lie scattered over the tops of numerous hills in this and adjoining townships.

T. 22 N., R. 10 E.

The surface of T. 22 N., R. 10 E., is a broad, nearly flat plateau which has been to some extent dissected by Horse Creek and its tributaries. The land in the valleys is underlain by the Ludlow lignitic member and Cannonball marine members of the Lance formation, and the plateau surface by the lower part of the Fort Union formation. The mantle of soil is heavy, and at only a few places is it possible to find natural rock exposures.

A thin bed of lignite in the Ludlow lignitic member crops out in the valley of Horse Creek but is concealed except at three places, in secs. 1, 2, and 23 (locations 874 873, and 872, respectively), at each of which some prospecting has been done and lignite has been removed for local use. The average thickness of the bed is less than 2½ feet. The sections measured at these places are as follows:

Sections of a lignite bed in the Ludlow lignitic member of the Lance formation in prospect pits in T. 22 N., R. 10 E.

Location 872. NE. ¼ sec. 23.

	Ft.	in.
Shale, bluish gray, sandy.		
Lignite, woody texture	2	8
Clay.		

Location 873. NE. ¼ sec. 2.

	Ft.	in.
Shale.		
Lignite	1	10
Bottom of bed covered with water.		

Location 874. SE. ¼ sec. 1.

	Ft.	in.
Shale, brown.		
Lignite	2	0
Bed covered with water.		

A lignite bed outcrops in the valley of a small stream in sec. 5, where it is less than 2 feet thick and was not mapped. The bed was reported to be 2 feet 9 inches thick in a well at location 875, in the NW. ¼ sec. 8, and it was said that in a deeper well in sec. 10 two lignite beds were penetrated, the upper one 2 feet 6 inches thick and the lower one 6 feet 6 inches thick.

No lignite could be found in the Fort Union formation in this township.

T. 23 N., R. 10 E.

The greater part of T. 23 N., R. 10 E., is occupied by the broad valley of the North Fork of Grand River, which flows from west to east. Between the valley and the extensive uplands to the north and south is a series of steep scarps separated by nearly level benches. The upland is underlain by the lower sandstone of the Fort Union formation, and the rocks that crop out in the valley belong to the

Ludlow lignitic and Cannonball marine members of the Lance formation, which are fairly well exposed at a few points along the river bluffs.

A thin bed of lignite in the Ludlow member crops out on the south side of the river and is well exposed in the river bluffs in the western half of the township. West of sec. 28 it is less than 2 feet thick and was not mapped. In sec. 28, however, it reaches a thickness of 3 feet 3 inches with a 3-inch parting 1 foot from the top (section 878, Pl. X). East of that place the bed was found only at location 877, on the east line of sec. 36, where it is 1 foot 5 inches thick.

T. 16 N., R. 11 E.

Several small areas of badlands are found along the stream courses in T. 16 N., R. 11 E., although a large part of the land is rolling and partly grass-covered. The soil, which is the result of the disintegration of the argillaceous shale of the Lance formation, is not especially fertile, hence farming has been attempted at only a few localities. The low divide between Antelope Creek on the south and Rabbit Creek on the north extends across the center of the township.

No lignite beds of value are exposed in this township, and although the bedrock is largely obscured by soil, there is little possibility that good lignite beds will be found beneath the surface, because the Lance formation contains only thin beds of lignite in this part of the field.

T. 17 N., R. 11 E.

North of Rabbit Creek, in the western part of T. 17 N., R. 11 E., the surface rises rapidly, culminating in secs. 7 and 8 in a narrow ridge, the top of which is about 250 feet above the level of the creek. To the south, however, except where cut by small streams, the surface is a rolling prairie. Rabbit Creek occupies a rather narrow, meandering channel cut several feet below the average valley level. Except along the north bank of Rabbit Creek there are very few rock exposures, the character and attitude of the underlying formations being obscured by a heavy mantle of soil. Numerous small farms are located in the broad, open valley that extends northward from Rabbit Creek through the center of the township.

The lower part of the Lance formation is exposed in the southern two-thirds of the township, along the valley of Rabbit Creek, and contains thin beds of lignite near the top. The Ludlow lignitic member outcrops in the ridges north of Rabbit Creek, where it contains one economically important bed of lignite about 100 feet above the base. There are numerous more or less resistant sandstone beds in it which give rise to the rugged ridges north of the main stream. All the strata dip very gently north.

One of the lignite beds near the top of the lower part of the Lance has been worked for several years at location 879, in sec. 7, at the Phillips mine, which in 1911 consisted of four drift entries from each of which rooms had been turned. From one of these entries, 200 feet long, lignite had been removed recently, but the others had been idle for more than a year. The bed in the mine ranges in thickness from 1 foot 9 inches to 2 feet 5 inches and has an excellent shale roof and floor. Practically no props have been necessary to keep the mine in good condition, except where part of the roof has been removed along the entries. The fresh lignite is hard and black, has cleavage planes fairly well developed, and shows little of the woody structure so prominent in most of the lignite of this region, thus suggesting that it should perhaps be classed as subbituminous, like the coal of near-by fields in eastern Wyoming and Montana. It is rather significant, however, that although differing markedly in physical properties, the lignite from this mine has almost the same chemical composition as that mined at the Jones mine, in T. 19 N., R. 10 E., and described on page 128. A sample of the lignite was taken from a room near the end of the longest entry in the Phillips mine, and the analysis of it (No. 12488) is given in the table on page 42.

In several small areas east of the Phillips mine the lignite has been burned, and the resulting red soil and rock indicate the former position of the bed. A bed supposed to be the same is exposed at location 881, on the east side of a small valley in sec. 17, and contains 3 feet 9 inches of lignite. Beyond this place to the east the bed could not be found. Other beds of lignite of lesser value occur near the top of the lower part of the Lance. The sections obtained at locations 879, 880, and 881 are shown in Plate XI. Others in secs. 16 and 17 are as follows:

Sections of lignite beds in the lower part of the Lance formation, in T. 17 N., R. 11 E.

[In addition to those shown on Pl. XI.]

No. on Pl. II.	Location.	Section.		No. on Pl. II.	Location.	Section.	
			Ft.in.				*Ft.in.*
882	SW. ¼ sec. 17..	Shale, brown.		883	NE. ¼ sec. 16..	Shale, brown, sandy.	
		Lignite.....	1 0			Lignite.....	1 4
		Shale brown.				Shale, brown.	

The thickest bed of lignite exposed in this township occurs in the Ludlow lignitic member of the Lance and outcrops well up in the ridge north of Rabbit Creek. No mines have been opened on the bed, although it contains 3 feet 8 inches of clean lignite at location 884 and 3 feet 10 inches at location 885.

T. 18 N., R. 11 E.

T. 18 N., R. 11 E., lies within the typical meadow area of Perkins County and the surface is generally flat and is grass-covered except where it is cultivated. The soil is the result of the disintegration of the sandy shale and soft sandstone of the Ludlow lignitic member of the Lance, and is fertile and well adapted to the raising of small grains, potatoes, etc. Only a very few tracts still remain unappropriated by the farmer. Strool, one of the thriving business towns of Perkins County, is in sec. 19. In secs. 26 and 27 there is a prominent ridge covered with brown quartzite bowlders, some of them several feet in diameter, which may belong to the White River formation.

Lignite has been mined for local use at the Shear ranch (location 887), in sec. 26, where there is reported to be about 3 feet of lignite. In August, 1911, the pit was filled with water, so that only 2 feet of lignite was exposed. Thin beds of lignite are reported to have been found in a few wells in this vicinity, but none of economic importance are known.

T. 19 N., R. 11 E.

The surface of T. 19 N., R. 11 E., shows a difference in altitude of at least 300 feet between the level of the valley on the north and the high bench land in the southern portion. Numerous small streams flowing northward into the South Fork of Grand River dissect the surface so that most of it is too rough to be used for farming. The surface rocks, which are fairly well exposed, belong to the Ludlow lignitic member of the Lance and dip slightly northeastward.

Two beds of lignite, on each of which one small mine has been opened, attain a thickness of more than 2 feet 10 inches. The upper bed, represented by sections 888 to 892, reaches a thickness of nearly 8 feet at the mine at location 890, in sec. 19. Considerable lignite has been removed from this mine by stripping the overburden, but in future development it will be necessary to drift because of the thick mantle of rock and soil which overlies the bed. As will be seen by referring to the sections on Plate XI, this bed varies considerably in thickness, but at a number of places it is thick enough to be profitably mined.

Approximately 65 feet lower in the section the bed that is mined at the Jones mine, in the township to the west, is represented by sections 894 to 898, Plate XI. At the time of examination in 1911 the mine at location 894, in sec. 20, consisted of one drift entry more than 50 feet long which was badly caved and inaccessible. The bed is 4 feet 7 inches thick at the mouth of the entry. The amount of lignite removed is not known, but evidently it is considerable. Although exposed at several other localities in the township the bed is not thick enough to be of value except at the abandoned mine.

In addition to the two beds mentioned, several thin beds are exposed at several localities and a number of sections were measured. All the lignite sections obtained in the township are shown graphically on Plate XI or are presented in the following table:

Sections of lignite beds in T. 19 N., R. 11 E.

[In addition to those shown on Pl. XI.]

No. on Pl. II.	Location.	Section.	Ft.	in.
892	SW. ¼ sec. 27..	Soil.		
		Lignite.....	1	4
		Shale, brown.		
893	NE. ¼ sec. 27..	Shale, brown.		
		Lignite.....	2	9
		Shale, brown.		
898	NW. ¼ sec. 21..	Top not exposed.		
		Lignite.....	1	8
		Shale, brown.		
899	NW. ¼ sec. 17.	Shale, brown.		
		Lignite.....		11
		Shale, brown...		2
		Lignite.....	1	1
		Shale.....	3	
		Lignite.....	1	3
		Total section.	6	5
		Total lignite..	3	3
900	SW. ¼ sec. 17..	Soil.....	8	
		Shale, brown.....		8
		Lignite.....	2	4
		Interval.....	10	6
		Lignite.....	1	4
		Shale, brown.		
		Total section.	22	10
		Total lignite..	3	8
901	SW. ¼ sec. 8...	Shale, brown.		
		Lignite.....		9
		Shale, brown...		4
		Lignite.....		6
		Shale, brown.....	2	0
		Lignite.....	1	7
		Shale, brown.		
		Total section.	4	2
		Total lignite..	2	10
902	SE. ¼ sec. 7....	Shale, brown.		
		Lignite.....		7
		Shale, brown..		2½
		Lignite.....		10
		Shale, brown..		3½
		Lignite.....		10
		Shale, brown..	1	6
		Lignite.....	2	6
		Shale, brown.		
		Total section	6	9
		Total lignite.	4	9
903	NE. ¼ sec. 8...	Shale, brown.		
		Lignite.....	2	6
		Shale, brown.		
904	SE. ¼ sec. 5....	Soil.		
		Shale, brown.....		8
		Lignite.....	1	6
		Shale, brown.		
		Total section	2	2
		Total lignite.	1	6
905	NE. ¼ sec. 5....	Shale, brown.		
		Lignite.....	2	8
		Shale, brown.		
906	SE. ¼ sec. 1....	Soil.		
		Lignite.....	2	3
		Shale, brown.		

T. 20 N., R. 11 E.

The southern part of T. 20 N., R. 11 E., is occupied by the broad valley of the South Fork of Grand River. South of the river the slopes are somewhat abrupt and the land is deeply dissected by small valleys, so that the rocks are fairly well exposed. North of the river the slopes are not nearly so steep, and good exposures can be found at only a few points.

The Cannonball marine member of the Lance formation crops out in the northern part of the township, and the Ludlow lignitic member of the Lance, about 300 feet in thickness, crops out in the valley slopes both north and south of the river. About 20 or 30 feet of the lower part of the Lance appears above the river level. The Ludlow

lignitic member, which is the surface rock over most of the township, consists of alternating beds of yellow sandstone, brown shale, and lignite. The sandstone in most places is unconsolidated and makes up nearly half of the total thickness.

Lignite beds are numerous, particularly in the lower part of the Ludlow member, but are everywhere thin and lenticular. In the river bluff at location 907, in the NE. ¼ sec. 28, five lignite beds are exposed in the lower 50 feet of the member. Some lignite has been removed for local use from the thickest of these beds. On the other side of the river, at location 908, in the NW. ¼ sec. 22, a still higher bed has been prospected and a considerable amount of lignite removed. The same bed was examined at location 909, in the NE. ¼ sec. 22, and at location 910, in the SE. ¼ sec. 13, and another still higher bed at location 911, in the NE. ¼ sec. 13. The sections measured at these places are given below. The same beds were examined at other points in the township but were not mapped.

Sections of lignite beds in Ludlow lignitic member of Lance formation in T. 20 N., R. 11 E.

Location 907. NE. ¼ sec. 28.

	Ft.	in.
Shale, light brown.		
Lignite		10
Shale, light brown	1	2
Lignite		7½
Shale, sandy	1	0
Lignite		7
Shale, brown and gray	3	3
Lignite		8½
Shale, brown	1	1
Lignite	1	7
Shale, brown		10
Shale, mudstone, blue	3	4
Lignite	2	3½
Shale and sandstone	29	0
Lignite		4½
Shale	3	0
Lignite		5
Shale.		
	50	1

Location 908. NW. ¼ sec. 22.

	Ft.	in.
Shale, brown.		
Lignite	2	7
Shale, brown.		

Location 909. NE. ¼ sec. 22.

	Ft.	in.
Shale, brown, sandy.		
Lignite	1	6
Shale		½
Lignite	1	0
Shale.		
Total section	2	6½
Total lignite	2	6

Location 910. SE. ¼ sec. 13.

	Ft.	in.
Shale, brown.		
Lignite		9
Shale, carbonaceous		1
Lignite	1	4
Shale.		
Total section	2	2
Total lignite	2	1

Location 911. NE. ¼ sec. 13.

	Ft.	in.
Shale.		
Lignite	2	0
Shale.		

T. 21 N., R. 11 E.

The surface of T. 21 N., R. 11 E., is a high plateau dissected by numerous streams. The divide between the North and South forks of Grand River, forming a broad upland prairie, crosses the northern part of the township. To the south a series of steep scarps separate the upland from the wide valley of Duck Creek.

The Ludlow lignitic member of the Lance formation outcrops in the valleys to the south but is very poorly exposed. Lignite beds in this member were found at a few points but are too thin to warrant mapping. Above the Ludlow member and separating it from the Fort Union formation is the Cannonball marine member of the Lance, which does not contain any beds of lignite. About 150 feet of the lower part of the Fort Union formation outcrops in the higher part of the township. Yellow sandstone is the most prominent rock in this part of the formation and outcrops on the steep sides of the hills, but there is also a considerable amount of shale, concealed for the most part by the mantle of soil on the smoother slopes.

The lignite bed that is mined near Lodgepole, in T. 21 N., R. 12 E., underlies the top of a high butte in secs. 9 and 10 of this township. At the east end of the butte (location 914, see Pl. X) it has been prospected to some extent. It is 6 feet thick, but as it is under only a few feet of cover it is weathered and the top part is mixed with sand. At the west end of the butte (location 913) the bed is under a better cover, but is thinner and contains partings of bone. The same bed is exposed in a butte at location 912, in the SE. ¼ sec. 18, where it is much thinner. The sections exposed at these places are shown graphically on Plate X. A few feet below the lignite bed is a persistent bed of very hard quartzitic rock, the residual blocks of which are thickly scattered over many of the higher buttes in this and adjoining townships. This bed is well exposed below the lignite bed at location 912, in sec. 18.

T. 22 N., R. 11 E.

The surface of T. 22 N., R. 11 E., is an irregularly rolling prairie, sloping gradually upward from the valley of the North Fork of Grand River, in the northern part of the township, to the plateau about the head of Lodgepole Creek, in the southeast corner. The outcropping rocks belong to the Ludlow lignitic and Cannonball marine members of the Lance formation and the lower part of the Fort Union formation. The two members of the Lance occupy the lower land in the northern part of the township and are concealed by the mantle of soil except at a few places. The contact of these two members and that between the Cannonball member and the Fort Union formation are effectually obscured, and the mapping is based on topographic data.

Lignite in the Ludlow member of the Lance is exposed at locations 918 and 917, in secs. 4 and 7, and is said to have been found in a well at location 916, in sec. 18. The beds at these localities are presumably at about the same horizon. The sections measured or reported at these places are as follows:

Sections of lignite beds in the Ludlow lignitic member of the Lance formation in T. 22 N., R. 11 E.

Location 916. NE. ¼ sec. 18.

	Ft.	in.
Lignite (reported in a well).....	2	0

Location 917. SW. ¼ sec. 7.

Lignite, burned.		
Shale, gray, sandy.....	9	0
Lignite.....		6

Location 918. SE. ¼ sec. 4.

	Ft.	in.
Shale.		
Sandstone, clayey.....	3	6
Lignite.....	1	8
Bottom of bed under water.		

No lignite beds were found in the lower 150 feet of the Fort Union, which consists chiefly of loosely cemented sandstone, but three small buttes in sec. 36 are underlain by the same bed that is being mined in the higher buttes near Lodgepole in T. 21 N., R. 12 E. In the western part of these buttes (location 915) the bed has a thickness of 5 feet 4 inches, with 1 inch of shale 1 foot 2 inches above the base, and is overlain by about 15 feet of sandstone and shale.

T. 23 N., R. 11 E.

The greater part of T. 23 N., R. 11 E., is occupied by the broad valley of the North Fork of Grand River, which flows eastward across the southern part of the township. The valley is separated by steep bluffs from the upland areas that extend northward from the State line at the north side of the township.

Fairly good sections of a part of the Ludlow lignitic member of the Lance formation are exposed in the bluffs of the river, but in the greater part of the township the underlying rocks are concealed by the mantle of soil. The Ludlow member is overlain by the Cannonball marine member of the Lance, and this in turn by the Fort Union formation, which outcrops in the steep hills in the northern part of the township and underlies the plateau farther north.

A thin bed of lignite in the Ludlow member of the Lance was examined at four places on the south side of the river, where it shows a range in thicknesss from 9 inches to 1 foot 5 inches. The sections are as follows:

Sections of a lignite bed in T. 23 N., R. 11 E.

Location 919. SW. ¼ sec. 31.

Shale, light brown, sandy.		
Lignite.....	1	5
Shale, brown, sandy.		

Location 920. SE. ¼ sec. 32.

Shale.		
Lignite, poor.....		9
Shale.		

Location 921. SW. ¼ sec. 34.

	Ft.	in.
Lignite.....		10

Location 922. SE. ¼ sec. 34.

Lignite.....	1	5

T. 16 N., R. 12 E.

North of Antelope Creek, which crosses the southern part of T. 16 N., R. 12 E., in a meandering course, the surface rises gradually to the rather prominent divide near the northern part of the township. The underlying rocks are largely obscured by soil, which has been formed by the disintegration of the soft clay shale of the Lance formation. The crest of the divide, in secs. 11 and 12, is capped by a few feet of the Ludlow lignitic member of the Lance. On account of the poor soil little or no attempt has been made to cultivate the land. No lignite bed of any value is known to outcrop in the township.

T. 17 N., R. 12 E.

Rabbit Creek crosses T. 17 N., R. 12 E., near its southern border in a deeply intrenched meandering channel, and receives all the drainage of the township. The surface is gently undulating and for the most part grass-covered, although there are numerous small areas of almost barren land along the valleys. The survey for a branch of the Chicago, Milwaukee & St. Paul Railway passes through the town of Daviston, in sec. 9.

The Lance formation underlies the whole area, the Ludlow lignitic member occupying the highlands in the northern part. The soil produced by the disintegration of the soft clay shale of the lower part of the Lance is not especially fertile, and there are many small areas which are destitute of vegetation and unattractive to the farmer. Rock exposures are very scarce, but from such data as could be obtained it is assumed that the formations dip northward about 20 feet to the mile.

At the base of the Ludlow lignitic member of the Lance formation there is a bed of lignite which is being mined at the Graff mine, in sec. 11, and the Rogers and Sexton mines, in the township to the east. The Graff mine (location 925) was opened in 1910 and consists of an open strip pit, from which several loads of lignite had been sold to the farmers. The bed, as indicated by section 925 on Plate XI, is composed of two benches of lignite separated by a shale parting 1 foot 2 inches thick, and it is overlain by a cross-bedded sandy shale. The lignite bed is irregular in thickness, and measurements in the workings of the mine show the upper bench to vary from 6 to 11 inches within a distance of about 20 yards. At location 926, in sec. 24, a bed occurring at the base of the Ludlow lignitic member is composed of five thin benches of lignite separated by shale partings 1 inch to 9 inches thick. The lowest and thickest bench contains 2 feet 2 inches of good lignite.

Two other sections of unimportant lignite beds were measured in the township as follows:

Sections of lignite beds in T. 17 N., R. 12 E.

[In addition to those shown on Pl. XI.]

Location 923. NE. ¼ sec. 8.

	Ft.	in.
Shale, blue	1	
Lignite		6
Shale, brown.		
Total section	1	6
Total lignite		6

Location 924. NE. ¼ sec. 9.

	Ft.	in.
Sandstone, soft, yellow.		
Lignite	1	2
Shale, brown		2
Lignite		4
Shale, brown.		
Total section	1	8
Total lignite	1	6

T. 18 N., R. 12 E.

The surface of T. 18 N., R. 12 E., lies in the gently undulating prairie of the Big Meadow, and exposures of rock are scarce. Thunder Butte Creek crosses the meadow from west to east in the northern part of the township and occupies a very wide, flat valley, below the level of which its meandering channel has been cut only slightly.

A small area of the White River formation is present on the top of the hill in sec. 21. Elsewhere the Ludlow lignitic member of the Lance formation constitutes the surface rock. To judge from the few exposures along the creeks, the rocks dip a little east of north at about 18 feet to the mile.

At location 927, in sec. 32, a bed of lignite reported to be 3 feet thick has been mined by stripping. No accurate measurements of the bed could be made, for when visited it was covered by water.

T. 19 N., R. 12 E.

The surface of T. 19 N., R. 12 E., is rough, being in the area north of the Big Meadow known locally as The Breaks. Between the high meadow in secs. 30, 31, and 32 and the valley of the South Fork of Grand River in secs. 1 and 2 there is a difference in altitude of nearly 300 feet. Several rather deep, steep-sided valleys cross the township and carry the run-off to Grand River. Exposures of rock are fairly good, although the area is generally grass-covered.

The Lance formation is the surface rock, the lower part of the formation being exposed in a narrow area along the South Fork of Grand River and the Ludlow lignitic member underlying all the higher land. The rocks dip toward the northeast at about 14 feet to the mile.

Several lenticular beds of lignite in the Ludlow lignitic member of the Lance formation outcrop in the township, but only one is of sufficient thickness to be considered commercially important. This bed is exposed in secs. 18 and 19 and is thought to be the same as the one mined at location 820 in the township to the west. Sections 828 and 829 (Pl. XI) show a thickness of 3 feet 3 inches and 3 feet, respec-

tively. Thin beds of lignite outcrop in other parts of the township, and the following sections were measured at the places shown on the map:

Sections of lignite beds in T. 19 N., R. 12 E.

[In addition to those shown on Plate XI.]

No. on Pl. II.	Location.	Section.	Ft.	in.
830	NW. ¼ sec. 17..	Soil.		
		Shale, brown.....	1	10
		Lignite.....	2	9
		Shale, brown.		
		Total section.	4	7
		Total lignite.	2	9
831	SW. ¼ sec. 8....	Shale, brown.....	5	0
		Lignite.....	1	0
		Shale, brown.		
		Total section.	6	0
		Total lignite.	1	0
832	NW. ¼ sec. 8...	Shale, brown.		
		Lignite.....	2	3
		Shale, brown.		
833	SE. ¼ sec. 33...	Lignite.....	1	6
834	SW. ¼ sec. 24..	.....do.....	1	8

No prospecting or mining has been done in this township.

T. 20 N., R. 12 E.

The South Fork of Grand River flows eastward across the southern part of T. 20 N., R. 12 E., and on both the north and the south its valley is bordered by a series of terraces.

The strata are in places well exposed in the bluffs of the river and of the smaller streams, so that in the township an almost complete section of the outcropping rocks may be examined. These rocks belong to the lower part of the Lance formation, the Ludlow lignitic member, the Cannonball marine member, and the lower part of the Fort Union formation. The Ludlow member, which occupies the greater part of the area, consists of alternating beds of yellow sandstone, brown shale, clay, and lignite. The upper 20 or 30 feet of the lower part of the Lance appears above the level of the river, and the Cannonball marine member and the lower sandstone of the Fort Union outcrop in the northern part of the township.

Lignite beds are numerous in the Ludlow member, which is exposed in the river bluffs, but the beds are lenticular and in only a few places have a thickness of over 2 feet. Probably the thickest bed outcrops in a few isolated buttes in the northern part of the township, where it has a thickness of about 2 feet 6 inches.

T. 21 N., R. 12 E.

T. 21 N., R. 12 E., lies on the upland between the North and South forks of Grand River. Lodgepole Creek flows southeastward across the township in a wide, flat valley which is bordered on both the north and the south by high rocky ridges, rising above the general plateau surface. The town of Lodgepole is in sec. 8.

Rocks of the Fort Union formation, about 200 feet in maximum thickness, outcrop in the greater part of the township, but the Cannonball marine member of the Lance formation occupies the valley of Lodgepole Creek, in the eastern part, and the lower portions of valleys of the small streams that flow toward the south. Two massive partly consolidated beds of sandstone give rise to the most prominent topographic features, the upper one capping the high ridges in the northern and central parts of the township, and the other, about 60 feet lower, capping numerous lower buttes in the eastern part.

The principal lignite bed of this part of the field lies about 20 feet above the lower of these two sandstones and probably 100 feet above the base of the Fort Union. It underlies the two principal ridges and a few outlying buttes. The southern ridge extends eastward from secs. 18 and 19 to sec. 15. Two local mines are in operation on the south side of this ridge, one in the SE. ¼ sec. 19 and the other, the Nelson (location 937), in the NW. ¼ sec. 29. Both are drift mines from which only a small amount of lignite is mined in summer but a much larger amount in fall and winter. A sample (No. 14354) was collected from the Nelson mine for analysis, the results of which are shown in the table on page 43. The thickness of the bed in this part of the township (sections 937, 938, and 939, Pl. X) ranges from 6 feet 2 inches to more than 7 feet. At location 940, on the north side of the ridge in sec. 18, the bed is 5 feet 7 inches thick but contains several thin partings of bone. Farther east the outcrop is concealed by the mantle of soil and the bed has not been found. An outlying butte at the corner of sec. 22, 23, 26, and 27 is also grass-covered, so that the outcrop of the lignite bed is concealed.

The northern ridge extends southeastward from secs. 4 and 5 to sec. 11. The outcrop of the lignite bed is concealed on the south side of the ridge except at location 941, near the north quarter corner of sec. 5, where the bed has a thickness of 6 feet 1 inch, with thin partings of bone. On the north side of the ridge the bed has been examined at locations 942, 943, 944, and 945 in secs. 11, 2, 3, and 4, respectively. At location 945 the bed has been mined by stripping. The lignite bed is exposed at locations 946 and 948, in an isolated butte in the NW. ¼ sec. 1, where it is 4 feet 8 inches and 4 feet 4 inches thick, respectively. North of the butte a small block has slumped down about 50 feet and a partial measurement of the bed was made at location 947 in the slumped block. All these sections are shown graphically in Plate X.

T. 22 N., R. 12 E.

The North Fork of Grand River flows southeastward across the north-central part of T. 22 N., R. 12 E., in a wide, flat valley. Grand River post office is on the river in sec. 17. This valley is separated from the high uplands on the north and south by a series

of terraces. A high sandstone-capped ridge extends eastward nearly across the southern tier of sections.

The rocks that outcrop in this township belong to the Ludlow lignitic and Cannonball marine members of the Lance formation and the Fort Union formation. The total thickness of the Fort Union is approximately 200 feet. Near the top are two massive, partly consolidated beds of sandstone, forming the caps of numerous buttes which stand out conspicuously, particularly in the northeastern and southern parts of the township.

The only valuable bed of lignite in this part of the South Dakota field lies about 20 feet above the lower of these two sandstones and underlies the high hills in the southern part of the township and in the adjoining township on the south. The sides of the hills are very steep, in places precipitous, and the lignite bed can be easily uncovered with a shovel at almost any point desired. The bed was examined at four points along the main ridge—at location 949, in the SW. ¼ sec. 36; at locations 950 and 952, in the SW. ¼ sec. 35; and at location 954, in the SW. ¼ sec. 34, and similar measurements were obtained in small outlying buttes at location 951, in the SE. ¼ sec. 34; at location 955, in the NE. ¼ sec. 33; and at location 958, in the SW. ¼ sec. 31. Small drift mines have been opened and lignite removed for local use at location 953, in the SE. ¼ sec. 35; at location 956, in the NW. ¼ sec. 33; and at location 957, in an outlying butte in the NW. ¼ sec. 32. The thickness of the bed, as shown by these measurements, ranges from 5 feet 4 inches to 8 feet 10 inches. The detailed sections are given on Plate X.

A thin bed of lignite in the Ludlow member of the Lance was examined in the river bluff at Grand River post office (location 959) and was observed but not studied at other places along the river. The section at this place is as follows:

Section of lignite bed at location 959, in the NW. ¼ NW. ¼ sec. 16, T. 22 N., R. 12 E.

	Ft.	in.
Sandstone.		
Shale, carbonaceous		8
Lignite	1	4
Shale, carbonaceous	1	4
Lignite		8
Sandstone, carbonaceous.		
Total section	4	0
Total lignite	2	0

T. 23 N., R. 12 E.

T. 23 N., R. 12 E., lies south of the divide between the North Fork of Grand River and Flat Creek. The plateau that stretches away to the north is separated in this township from the lower land on the south in some places by moderately steep scarps and elsewhere by smooth slopes.

The Ludlow lignitic and Cannonball marine members of the Lance formation outcrop in the deeper valleys; the sandstone and shale of the lower part of the Fort Union formation underlie the plateau region. The line separating the two members of the Lance formation is only approximate, inasmuch as the surface is heavily grass-covered and there are very few natural rock exposures.

A high ridge nearly covered with quartzitic bowlders extends from the east into sec. 24 and is underlain by a bed of lignite approximately 3 feet thick, which, however, is not exposed in this township. At a lower level in the NW. ¼ SE. ¼ sec. 24 a thin bed has been prospected to some extent at location 960, but its thickness is only 1 foot 1 inch.

T. 16 N., R. 13 E.

The surface of T. 16 N., R. 13 E., is deeply dissected by Rabbit and Antelope creeks, and because of the easily weathered character of the rocks only a few good exposures occur. Rabbit Butte, in sec. 7, rises 100 feet or more above the surrounding country and is a conspicuous landmark. Soil derived from the clay shale of the Lance formation does not make good farm land, and consequently there are only a few small areas which have been cultivated, much of the land being almost barren of vegetation.

With the exception of a small area of the Ludlow lignitic member of the Lance formation in Rabbit Butte, the surface of this township is composed of the somber-colored shale of the lower part of the Lance, which here is not lignite-bearing. Two thin beds of lignite near the base of the Ludlow member are exposed in Rabbit Butte and are shown in the following section:

Section at Rabbit Butte, location 961, T. 16 N., R. 13 E.

	Ft.	in.
Shale, brown.		
Lignite	2	2
Shale, brown	25	0
Lignite	1	5
Shale, brown.		
Total section	28	7
Total lignite	3	7

T. 17 N., R. 13 E.

Rabbit Creek crosses sec. 31, T. 17 N., R. 13 E., and with its two main southward-flowing tributaries drains the entire township. The surface slopes gradually upward from the level of the creek to the meadow land at the northern boundary. It is rolling and grass-covered, and exposures of rock are scarce. The soil in most of the township is the result of the disintegration of the soft sandstone of the Ludlow lignitic member of the Lance formation. It is fertile, and numerous small farms are being cultivated.

The somber-colored shale of the lower part of the Lance formation outcrops in the southern part of the township, and the sandy shale and sandstone of the Ludlow lignitic member underlie the higher northern part.

At the base of the Ludlow member there is a bed of lignite which in the vicinity of the Rogers and Sexton mines is thick enough to be of economic importance. To the east and west, however, along its outcrop the bed is worthless, being split into several benches at location 926, in sec. 24, of the township to the west. (See p. 140.) At location 966 (see Pl. XI), in sec. 29, the bed is represented by only 2 feet 2 inches of lignite split into two benches.

The Rogers mine at location 962, in sec. 18, is an open strip pit from which a large amount (probably several hundred wagon loads) of lignite has been mined by stripping off the 15 to 20 feet of overburden with a scraper. The mine has been operated for several years, supplying a large local demand. The lignite is bright, hard, and nearly black and has fairly well developed cleavage planes. Numerous aggregations of iron pyrite are present along the joint planes of the bed. The part of the bed mined is 5 feet thick.

The Sexton mine, at location 964, about half a mile to the east, on the same bed, which at this place has a thickness of 4 feet 11 inches, is worked by the same method, and the lignite is sold locally. This mine has been opened more recently than the Rogers mine, but nevertheless several hundred wagon loads of fuel have been removed from it.

South and east of the mines the bed is burned along its outcrop, but it can be traced easily by the resulting red soil and rock. Sections 962 to 967 (Pl. XI), which were measured in this township, illustrate the irregularities of the lignite bed occurring at the base of the Ludlow member in this part of the field.

T. 18 N., R. 13 E.

The greater part of the surface of T. 18 N., R. 13 E., is rolling meadow or farm land. The maximum difference in altitude between the lowest valley land and the highest butte is not much more than 100 feet. Thunder Butte Creek drains almost the entire township, passing across it a little south of the center in a broad, flat valley, the sides of which constitute the low dividing ridge between the South Fork of Grand River on the north and Rabbit Creek on the south. The area is largely under cultivation, inasmuch as the soil, which is derived mainly from the sandy beds of the Ludlow lignitic member of the Lance formation, is very fertile. Bison, the county seat of Perkins County, is a thriving town of 100 or more people in sec. 13.

Along the southern margin of the township the lower part of the Lance formation is exposed in a small area. Elsewhere the surface

rocks belong to the Ludlow member. No bed of lignite is known to outcrop in the township, and no valuable bed has been found in the wells of the area.

T. 19 N., R. 13 E.

The South Fork of Grand River crosses T. 19 N., R. 13 E., near its northern boundary and receives drainage from the entire area. To the south the surface rises about 480 feet in very rugged slopes to the altitude of the Big Meadow. Several well-defined valleys heading along the southern margin of the township cross it in a northerly direction, at nearly right angles to the valley of the South Fork of Grand River. North of the river the surface rises abruptly, especially near Breckenridge post office, where the river flows very close to a cliff that reaches a height of nearly 100 feet above the valley. Little farming has been done in the area because the surface is too rough. Although the surface is largely grass-covered, there are numerous exposures from which to study the bedrock.

A narrow area in the valley of the South Fork of Grand River is underlain by the lower part of the Lance formation (see Pl. II), but the Ludlow lignitic member of the Lance occupies the major part of the township. The strata dip very slightly northeastward.

Two small strip mines on a bed of lignite which outcrops in secs. 27, 28, 33, and 34 have been opened by the farmers of the vicinity to supply their own needs, but, as indicated by sections 968 and 969 (Pl. XI), taken at the mines, the thickness of the bed at neither place is sufficient to warrant extensive mining. Thin lignite beds are exposed at several other places but have not been mined or prospected. The lignite bed at the base of the Ludlow member is exposed at locations 972 to 974, but at no place is there a sufficient thickness to make mining attractive.

Sections of lignite beds in T. 19 N., R. 13 E.

[In addition to those shown on Pl. XI.]

No. on Pl. II.	Location.	Section.	Ft.	in.
970	SW. ¼ sec. 25..	Soil.		
		Lignite	2	0
971	SE. ¼ sec. 26..	Shale, brown.		
		Lignite	2	6
		Shale, drab	5	
		Lignite	1	2
		Shale, brown.		
		Total section.	8	8
		Total lignite..	3	8
972	NW. ¼ sec. 5..	Clay, sandy.		
		Lignite		8
		Shale, brown	2	10
		Lignite	2	6
		Total section.	6	0
		Total lignite..	3	2
973	NE. ¼ sec. 10..	Lignite		10
974	NE. ¼ sec. 11..	Lignite	1	1

T. 20 N., R. 13 E.

The low grass-covered divide that crosses near the center of T. 20 N., R. 13 E., in an easterly direction separates the drainage of the South

Fork of Grand River on the south from that of Lodgepole Creek on the north. On either side the surface slopes gradually away from the divide and is traversed by broad valleys. A large proportion of the surface is under cultivation, and good rock exposures are very scarce.

The surface rocks belong to the Ludlow lignitic and Cannonball marine members of the Lance formation and the Fort Union and White River formations. The White River occupies a small area on top of the divide in sec. 16. The boundaries of the other formations, as shown on the map (Pl. II), are drawn only approximately.

No bed of lignite of any value is known in the township, but beds less than 4 inches thick are reported to have been found in a number of wells south of Cole post office.

T. 21 N., R. 13 E.

The upland between Lodgepole Creek and the North Fork of Grand River extends from the western border of T. 21 N., R. 13 E., nearly across the township. The plateau has been largely dissected by the two streams and their numerous tributaries.

The rocks that outcrop in the township belong to the Cannonball marine member of the Lance formation and the Fort Union formation, but no attempt was made in the field to map the contact between the two, and the line shown on the map is therefore only approximate. A massive, partly consolidated bed of sandstone in the Fort Union forms the caps of a number of prominent buttes that rise above the general plateau level in the western part of the township. The surface of the township is for the most part grass-covered, and natural exposures are few except in the bluffs of the North Fork of Grand River, which flows eastward across the northeast corner of the township.

No lignite beds were found or reported in this township.

T. 22 N., R. 13 E.

A group of high rocky hills occupies the central part of T. 22 N., R. 13 E., rising conspicuously above the valley of the North Fork of Grand River, which flows southeastward across the southwestern part of the township. To the north the rocky hills give way to a high rolling prairie.

The rocks that outcrop in this township belong to the Ludlow lignitic and Cannonball marine members of the Lance formation and the lower part of the Fort Union formation. The steep bluffs of the North Fork of Grand River furnish good exposures of parts of the Ludlow and Cannonball members, and a prominent bed of sandstone in the Fort Union forms the caps of the prominent buttes. With

these exceptions, the underlying rocks are for the most part concealed by a heavy mantle of soil.

A bed of lignite which is correlated with the bed that is being mined near Lodgepole, S. Dak., and north of Haynes, N. Dak., underlies three small buttes in secs. 1 and 2. At location 975, in sec. 2 (see Pl. X), which is the only point where the bed is exposed, it has a thickness of 2 feet 6 inches. The horizon of this bed is above the tops of the hills in the central part of the township.

T. 23 N., R. 13 E.

The surface of T. 23 N., R. 13 E., is a rolling upland prairie, dissected by numerous small valleys. The rocks that outcrop in the township belong to the Fort Union formation and are fairly well exposed along the valleys in the western part of the township. In the northeast a partly consolidated bed of sandstone forms the caps of numerous low hills that rise abruptly from the nearly flat valleys. A high rocky ridge extends westward from sec. 21 of this township into sec. 24, T. 23 N., R. 12 E., and is underlain by a bed of lignite which is correlated with the bed that is being mined near Lodgepole, S. Dak., and north of Haynes, N. Dak. In this township the bed has been mined to some extent by stripping at location 976 in the SW. ¼ sec. 19, and at location 977, in the SW. ¼ sec. 21, where the bed has a total thickness of 3 feet 4 inches and 5 feet 3 inches, respectively. (See Pl. X.) At location 977 the bed is split into four benches by shale and bone partings. The same bed underlies an isolated butte in secs. 33 and 34, but the outcrop is covered by the mantle of soil.

T. 16 N., R. 14 E.

The surface in T. 16 N., R. 14 E., is moderately dissected by small streams and only partly covered with grass. Soil resulting from the disintegration of the soft argillaceous shale that forms the surface rock does not make good farm land, hence very few farmers have settled in the area. The lower part of the Lance formation, which underlies this area, contains no lignite in this part of the field.

T. 17 N., R. 14 E.

The valleys of Thunder Butte Creek and its main tributary, Lone Tree Creek, constitute a large part of T. 17 N., R. 14 E. Away from the streams the surface rises gradually in a grass-covered slope to a maximum altitude of less than 100 feet above the level of the valley floors. Numerous farmers have recently taken up land in this part of the State, but continued drought has produced discouraging results and many of them have already been forced to abandon their claims and leave the country. Although there are small areas in which the soil will produce good crops when properly cared for, a large part of

the township is destined to remain uncultivated. Except for a thin covering of the Ludlow lignitic member of the Lance formation on a few of the higher areas, the surface rocks belong to the lower part of that formation and dip northward at about 20 feet to the mile.

A single bed of lignite is exposed along Thunder Butte Creek in sec. 3, where the following section was measured:

Section of lignite bed at location 978, in sec. 3, T. 17 N., R. 14 E.

	Ft.	in.
Shale, drab	2	6
Lignite	2	8
Shale, drab.		
Total section	5	2
Total lignite	2	8

T. 18 N., R. 14 E.

T. 18 N., R. 14 E., lies in the meadow area, and its surface is accordingly only very slightly dissected. The maximum difference in altitude between the valley of Thunder Butte Creek, on the southwest, and the conspicuous buttes in the northeastern part of the township is probably less than 150 feet, and over most of the area there is a difference of less than 50 feet. There are a large number of well-established farms in the township, and only a small proportion of the land has not been put under cultivation. Five small white buttes in the northeastern part of the township rise about 50 feet above the average level of the meadow and stand out as conspicuous landmarks in a generally flat, grass-covered region.

Rocks of the lower part of the Lance formation crop out along Thunder Butte Creek, in the southwest corner, and are overlain with apparent conformity by the sandy Ludlow lignitic member of the Lance formation, which occupies the surface of nearly all the remainder of the area. The maximum thickness (200 feet) of the Ludlow in this township is represented in the northeastern part. The five prominent buttes are formed by about 45 feet of clay and sandstone of the White River formation from which fossils of Oligocene age were obtained. (See Pl. IV, *A*, p. 32.)

Exposures of rock in this township are very rare, and neither they nor the available well records indicate the presence of valuable lignite beds in this part of the field.

T. 19 N., R. 14 E.

The surface of T. 19 N., R. 14 E., is deeply dissected by several nearly parallel valleys, and most of the area is not suitable for farming. Between the South Fork of Grand River and the top of the small white butte in sec. 34 there is a difference in altitude of nearly 450 feet. Although the surface is rough, a mantle of soil covers most of it and obscures the rock structure.

A considerable area in the valley of the South Fork of Grand River is occupied by the shale of the lower part of the Lance formation, but the rest of the township is covered by rocks of the Ludlow lignitic member of the Lance, with the exception of a small prominent butte in sec. 34, which is capped by 45 feet of clay of the White River formation. The rocks dip gently to the north.

There are practically no exposures of the lignite except where farmers have uncovered the beds to procure their fuel supply. Sections 979 and 981 to 986, Plate XI, were measured in small mines. None of the mines have been developed on a large scale, but each has furnished several wagon loads of fuel. The mining has been done by stripping the rock overburden, in places as much as 15 feet, and then digging up the lignite. Above the lignite at the small mine at location 982, sec. 35, there is about 150 feet of overburden, so that future mining here will have to be done from drift openings. The beds mined range in thickness from 1 foot 1 inch at location 985, in sec. 6, to 2 feet 3 inches at location 982, in sec. 35. The section given below was measured near the top of a high hill in sec. 32, on what is assumed to be the same bed as that opened at location 981, in sec. 30:

Section of lignite bed at location 980, in sec. 32, T. 19 N., R. 14 E.

	Ft.	in.
Shale, brown.		
Lignite	1	3
Sandstone, yellow		6
Lignite	1	5
Shale, brown.		
Total section	3	2
Total lignite	2	8

In the NE. ¼ NW. ¼ sec. 12 the outcrop of a bed reported to be about 1 foot thick is covered by gravel, but a near-by rancher has mined a small amount of lignite by stripping off the gravel.

T. 20 N., R. 14 E.

The South Fork of Grand River occupies a broadly meandering course in the wide valley in secs. 25 and 36, T. 20 N., R. 14 E. Near the valley the slopes are abrupt, but elsewhere in this township the surface is a rolling grass-covered prairie. Several well-developed valleys cross the township from west to east but do not contain running water for any large part of the year. Lodgepole Creek, which crosses the township near the northeast corner, follows a meandering course in a rather narrow valley. A large portion of the land is under cultivation and makes very good farm land.

Rocks belonging to the Ludlow lignitic and Cannonball marine members of the Lance formation and dipping northward at low angles form the surface of nearly the entire township. The lower part of the

Lance is exposed in small areas along the South Fork of Grand River in the southeastern part and along Lodgepole Creek in the northeast corner.

A thin bed of lignite occurs at the base of the Ludlow member in the northern part of the area and has been mined at a small strip mine at location 989, in sec. 1, where it is only 2 feet 6 inches thick. Two beds of lignite are exposed in sec. 13, as follows:

Sections of lignite beds in T. 20 N., R. 14 E.

[In addition to those shown on Pl. XI.]

Location 987.

	Ft.	in.
Sandstone, yellow, soft.		
Lignite, with pyrite	2	5
Shale, carbonaceous		4
Lignite		3
Shale.		
Total section	3	0
Total lignite	2	8

Location 988.

	Ft.	in.
Shale, yellow.		
Lignite	1	8
Shale, brown.		

T. 21 N., R. 14 E.

From the divide near the center of T. 21 N., R. 14 E., the land slopes rather abruptly to the North Fork of Grand River on the north and Lodgepole Creek on the south, both of which are perennial streams. The surface, though generally grass-covered, is dissected by numerous small streams but is not so rough as to prevent cultivation. Good wagon roads follow nearly all the section lines and provide avenues along which produce may be hauled to the Chicago, Milwaukee & St. Paul Railway, which is about 15 miles to the north. Settlers who have taken up land in this part of the State have been fairly successful in raising crops of small grains, potatoes, etc.

Shale of the lower part of the Lance formation is exposed along the valleys of Lodgepole Creek and the North Fork of Grand River, but the surface of the greater part of the township is composed of the soft sandstone and sandy shale of the overlying Ludlow lignitic and Cannonball marine members of the Lance.

Two thin lignite beds outcrop near the base of the Ludlow member at location 990, in sec. 11, where the following section is exposed:

Section of lignite beds at location 990, sec. 11, T. 21 N., R. 14 E.

	Ft.	in.
Clay.		
Lignite	1	6
Interval	50	0
Lignite	1	2
Shale, brown		7
Lignite		10
Shale, brown.		
Total section	54	1
Total lignite	3	6

The outcrop of neither of the beds could be followed beyond the single cut bank, and the beds are therefore supposed to represent local lenses.

No mining has been done in this particular area, but it is probable that the 3 foot 4 inch bed of lignite which is mined at the Brady mine, in sec. 6 of the township to the southeast, may underlie a portion of sec. 36 of this township and possibly may be mined there in the near future.

T. 22 N., R. 14 E.

The surface of T. 22 N., R. 14 E., is an irregularly rolling prairie with numerous small valleys and a few prominent buttes. White Butte, a conspicuous landmark in secs. 21 and 28, is capped with nearly white sandstone, probably a part of the White River formation. The rocks underlying the remainder of the township belong to the Cannonball marine member of the Lance formation and the Fort Union formation. A partly consolidated bed of sandstone in the Fort Union forms the caps of a few prominent buttes and outcrops high on the sides of White Butte. A bed of lignite about 20 feet above this sandstone underlies White Butte and another prominent butte in sec. 15. The bed has been mined from a drift at the south end of the latter butte (location 992), but at the time the township was examined, in June, 1912, the lignite in the mine was burning and the mine had been closed. The section measured at the mouth of the mine contains a total of 6 feet 4 inches of lignite, but on White Butte, where considerable prospecting has been done, the bed contains a large proportion of shale. The detailed sections (991 and 992) are shown on Plate X.

T. 23 N., R. 14 E.

The surface of T. 23 N., R. 14 E., is a rolling prairie, interrupted by a number of high rocky buttes in the western part. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the north border of the township. White Butte post office is on that line in sec. 3. The outcropping rocks belong to the Cannonball marine member of the Lance formation and the Fort Union formation but are for the most part concealed by a heavy mantle of soil. A partly consolidated sandstone in the Fort Union forms the caps of the prominent buttes in the western part of the township. No lignite was found or reported in this township.

T. 16 N., R. 15 E.

A rather pronounced grass-covered plateau-like divide, separating the drainage of Thunder Butte Creek on the north from that of Rabbit Creek on the south, crosses T. 16 N., R. 15 E., from northwest to southeast and rises more than 100 feet above the valley levels. On each side of this upland, where the soil is the result of the disinte-

gration of the clay shale of the lower part of the Lance formation, there are numerous small areas of barren, unattractive land. Nevertheless, a number of small farms have been located in the valley of Thunder Butte Creek. The surface south of the divide descends in a rather steep, intricately dissected, and nearly barren slope toward Rabbit Creek. Chance, a small but thriving town, is a short distance north of this township and is the market place for the inhabitants of this vicinity.

From 30 to 60 feet of beds belonging to the Ludlow lignitic member of the Lance formation are exposed in an area about a mile in width along the divide. At the base of the yellow sandy beds of the Ludlow member there is a bed of lignite which, although not of great value, has been prospected and mined at several places. At the Rail mine, location 997 in sec. 20 (see Pl. XI), the following section is exposed:

Section at Rail mine, in sec. 20, T. 16 N., R. 15 E.

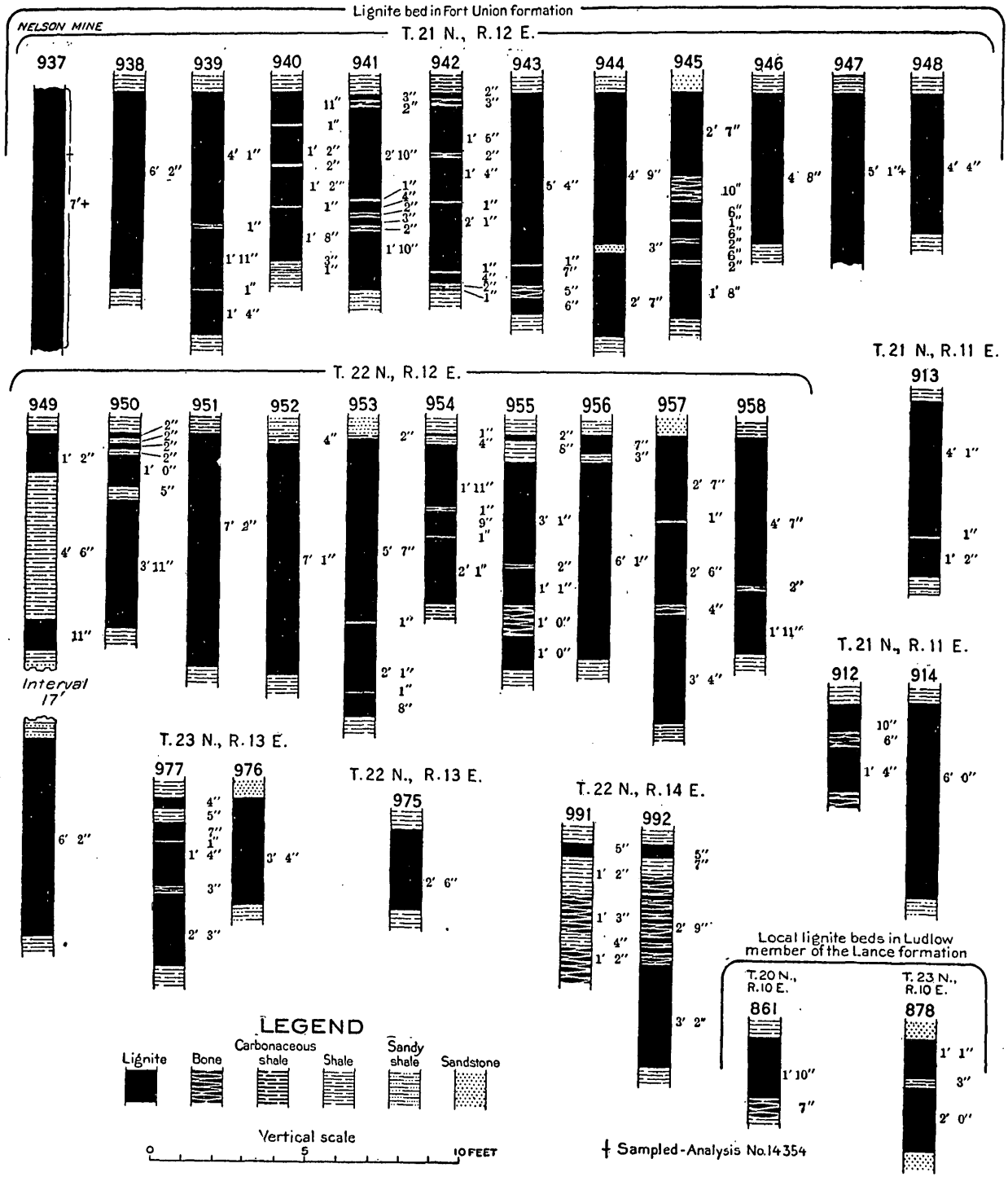
	Ft.	in.
Sandstone, yellow, soft, massive	4	0
Shale, yellow, argillaceous	3	0
Shale, drab	2	11
Shale, carbonaceous		7
Lignite		1½
Shale, drab		3
Lignite		9
Sandstone		½
Lignite	1	4
Shale, brown		7
Lignite		8
Shale, black.		
Total section	14	3
Total lignite	2	10½

The mine was opened in 1908 by Alexander Rail, and considerable lignite has been removed and sold to the near-by farmers at $3 a double box-wagon load. It has been possible so far to mine the lignite by stripping the comparatively thin cover, but as the overburden beyond the present workings is about 50 feet thick, it will be necessary to abandon the stripping method and resort to drifting.

The following is a detailed section of the same bed at the Wilson mine, at location 998, in sec. 21:

Stratigraphic section at the Wilson mine, at location 998, sec. 21, T. 16 N., R. 15 E.

	Ft.	in.
Clay, pink, shaly	1	6
Sandstone and shale, yellow, sandy	5	0
Shale, drab	3	6
Shale, carbonaceous		7
Lignite		1½
Shale, drab		3



LIGNITE SECTIONS IN PERKINS COUNTY, S. DAK.

In area examined by E. Russell Lloyd.

	Ft.	in.
Lignite		10
Sandstone		½
Lignite		9
Shale, brown, with lenses of lignite		5
Lignite		2
Shale, drab, sandy		5
Lignite		7
Shale, black.		
Total section	14	2
Total lignite	2	5½

This is a small strip mine opened in 1908 to supply the needs of the owner, and little if any lignite has been sold. The present workings have necessitated the stripping of only a small amount of overburden, but further development will probably require drifting, as beyond these workings the overburden is from 40 to 50 feet thick.

The same bed of lignite has been mined on a small scale in sec. 27, where the section is as follows:

Section of lignite bed at location 1000, sec. 27, T. 16 N., R. 15 E.

	Ft.	in.
Shale, yellow, sandy.		
Lignite	1	6
Lignite, poor, bony		6
Shale, brown.		
	2	0

The mine, being located near the head of a narrow, steep-sided gulch, is not easily accessible and therefore will probably not be much further developed.

The following sections of the same bed are exposed at the locations shown on the map but are not shown graphically on Plate XI:

Sections of lignite bed in T. 16 N., R. 15 E. (in addition to those shown in Pl. XI).

No. on Pl. II.	Location.	Section.	Ft.	in.
993	SW. ¼ sec. 17..	Shale, brown.		
		Lignite	2	2
994	NW. ¼ sec. 20..	Shale, brown.		
		Lignite	1	5
		Shale, brown		8
		Lignite		3
		Shale, brown.		
		Total section	2	4
		Total lignite	1	8
995	NW. ¼ sec. 20..	Shale, drab.		
		Lignite		9
		Shale, brown, sandy	1	5
		Lignite		3
		Shale, brown		4
		Lignite		2
		Shale, brown.		
		Total section	2	11
		Total lignite	1	2
996	NW. ¼ sec. 20..	Shale, drab.		
		Lignite		10
		Shale, drab		2
		Lignite		8
		Shale, brown.		
		Total section	1	8
		Total lignite	1	6
999	NE. ¼ sec. 17..	Soil	1	6
		Lignite, weathered		9
		Shale, drab	1	8
		Lignite		11
		Shale, drab.		
		Total section	4	10
		Total lignite	1	8
1001	NW. ¼ sec. 34..	Bone	1	6

T. 17 N., R. 15 E.

Thunder Butte Creek crosses T. 17 N., R. 15 E., from west to east near the southwest corner in a very crooked meandering channel cut several feet below the average valley level. On each side the surface rises gradually in a grassy prairie broken here and there by rather sharp ridges or buttes. Chance, in sec. 28, although at present 45 miles from a railway, is one of the prosperous towns of the region. The line surveyed for the proposed extension of the Chicago, Milwaukee & St. Paul Railway from Firesteel passes within a short distance of the town and should the railway be constructed according to that survey, Chance will undoubtedly become a very important shipping point for grain and produce grown in The Meadow and surrounding area. The town is now connected with the railway at Lemmon, to the north, by daily stage through Meadow.

Most of the township is meadow or cultivated land, but there are a few exposures of rock along the streams. With the exception of the somber-colored shale of the lower part of the Lance formation in the valley of Thunder Butte Creek the surface rock belongs to the Ludlow lignitic member of that formation. The rocks appear to dip northwestward at about 13 feet to the mile.

Lignite is exposed at only two places in the township, neither of which have attracted the attention of prospectors. At location 1002, in sec. 20, there is a bed 1 foot 8 inches thick, and at location 1003, in sec. 17, there is a bed 1 foot 1 inch thick.

T. 18 N., R. 15 E.

The surface of T. 18 N., R. 15 E., is gently rolling meadow or farm land with only a few exposures of rock along the small streams. The soil is the result of the disintegration of the soft sandy shale and sandstone of the Ludlow lignitic member of the Lance formation and will produce good crops of small grains, potatoes, etc., when care is taken to make the best use of the 10 to 20 inches of annual rainfall. Meadow, one of the older towns of Perkins County, is in sec. 13 and is the distributing point for a large area in this part of the field. Mail for the surrounding country is brought to Meadow from Lemmon, 35 miles to the north, by daily automobile stage. Wagon roads of the best type are to be found along section lines in this part of the field.

Lignite is exposed at three places in the township. At location 1005, in sec. 11, a bed reported to be from 1 foot 2 inches to 1 foot 6 inches thick has been uncovered and several loads of lignite have been removed. At location 1006, in sec. 36, a bed 1 foot 8 inches thick with a 2-inch parting near the middle has been worked by the near-by farmers. At both mines the lignite was covered by water in September, 1911, and detailed sections could not be measured. At location 1004 the following section is exposed:

Section of lignite bed at location 1004, in the NE. ¼ sec. 10, T. 18 N., R. 15 E.

	Ft.	in.
Lignite		4
Shale, brown	1	11
Lignite	1	6
Shale, brown.		
Total section	3	9
Total lignite	1	10

T. 19 N., R. 15 E.

From the general level of the Big Meadow along the southern border of T. 19 N., R. 15 E., the surface slopes gradually in a northwesterly direction toward the South Fork of Grand River, which crosses the southern part of the township to the northwest. Two wide, open valleys traverse the township from southeast to northwest and receive most of the run-off from this part of the field. Although the surface is considerably broken by ridges and valleys, the soil is fertile enough to encourage cultivation, and at the time of examination, in 1911, a large number of small farms had been established in this and adjacent townships. Lemmon, the nearest railway town, on the Chicago, Milwaukee & St. Paul Railway, about 25 miles to the north, is the shipping point for this part of the field.

With the exception of small areas in the lowlands in the northwest corner, where the lower part of the Lance formation is exposed, the surface rocks of the township belong to the Ludlow lignitic member of the Lance. The lower rocks are soft clay shale and form a poor soil, but the sandy shale and soft sandstone of the overlying Ludlow lignitic member produce a fertile sandy loam which in most of the area is grass-covered or cultivated. Exposures of bedrock are scarce.

A bed of lignite at location 1009 (see Pl. XI), in sec. 4, at the base of the Ludlow member, has been mined by the farmers of the vicinity. From 8 to 10 feet of overburden was removed with a scraper in order to obtain the lignite.

Thin beds of lignite are exposed at two other localities in the township, but their outcrops could not be followed far beyond the places at which the sections were measured:

Sections of lignite beds in T. 19 N., R. 15 E.

Location 1007. Sec. 34.

	Ft.	in.
Shale, brown	1	9
Lignite		3
Shale, brown		6
Lignite		3
Shale, brown	1	6
Lignite	1	11
Shale, brown.		
Total section	6	2
Total lignite	2	5

Location 1008. Sec. 6.

	Ft.	in.
Shale, drab.		
Lignite	1	2
Shale, carbonaceous		4
Shale, yellow, sandy.		
Total section	1	6
Total lignite	1	2

That the lignite beds described are not persistent is indicated by the fact that the bed exposed in sec. 34 is not present in a well 152 feet deep less than 1 mile to the southeast, where the surface is not more than 50 feet higher than that at location 1007.

T. 20 N., R. 15 E.

The South Fork of Grand River, which crosses T. 20 N., R. 15 E., from southwest to northeast, follows a meandering course in a valley about half a mile in width, along each side of which are terraces standing about 30 feet above the present river channel. Beyond the terraces the surface rises in rugged hills to a maximum height of more than 200 feet above the river. Away from the sandy valley bottoms the land is in many places under cultivation, although the surface is too uneven to make ideal farm land. The route of the automobile stage between Lemmon and Meadow crosses the eastern part of the township.

The valley of the South Fork of Grand River and its tributaries is occupied by the somber-colored shale of the Lance formation; the highlands on each side are formed by the yellow sandstone and sandy shale of the Ludlow lignitic and Cannonball marine members of the Lance.

The only bed of lignite that outcrops in the township occurs at the base of the Ludlow member and has been mined at several localities. The Kirkland mine at location 1010 (see Pl. XI), in sec. 23, consists of a strip pit 80 by 30 feet, from which lignite has been mined and sold to near-by farmers. The lignite at this point is only 2 feet thick.

The Brady mine at location 1014, in sec. 6 (see Pl. XI), on the north side of Lodgepole Creek, was worked by stripping in October, 1911. About 150 wagon loads of lignite had been removed and sold to the farmers in the vicinity.

About the same amount of lignite had been taken from a mine a short distance to the east (location 1015), which when visited had been abandoned, probably because it had become necessary to strip about 35 feet of overburden in order to obtain lignite. The bed at this point is 3 feet 7 inches thick.

An area about 50 by 100 feet was mined out at a small strip opening at location 1013, in the SW. ¼, sec. 6, where the bed shows the following section:

Section of lignite bed at location 1013, in sec. 6, T. 20 N., R. 15 E.

	Ft.	in.
Shale, bluish, sandy.		
Lignite		2
Shale, bluish, sandy	2	2
Lignite	3	
Shale, dark brown.		
Total section	5	4
Total lignite	3	2

Measurements of the bed were taken at several other places, as follows:

	Ft.	in.
Location 1011, sec. 17	1	2
Location 1012, sec. 7	1	10
Location 1016, sec. 1		11
Location 1017, sec. 13	1	6

T. 21 N., R. 15 E.

The North Fork of Grand River flows across T. 21 N., R. 15 E., in a meandering channel cut 30 to 40 feet below the terrace level on either side and joins the main river in sec. 26, near the town of Seim. Away from the main terrace the surface rises in a grass-covered slope, broken here and there by small areas of rough topography in which the bedrock has been exposed by erosion. Many farmers have settled in the area and are meeting with some success in raising small grains. Seim, a small town in sec. 26 on the stage route between the railway at Lemmon and Meadow, to the south, has a single store and a creamery. Being less than 15 miles from the Chicago, Milwaukee & St. Paul Railway, to the north, the farmers of this area are within easy reach of a market for their produce.

The Ludlow lignitic member of the Lance formation is probably present in the southern part of the township, but in the northern part the Cannonball marine member of the Lance directly overlies the lower part of the formation. This part of the field was examined in detal prior to the differentiation of the Cannonball and Ludlow members, but it seems evident that in this general region the two grade laterally into each other.

A bed of lignite 2 feet 5 inches thick is exposed at the base of the Ludlow lignitic member at location 1017A (see Pl. XI), in sec. 32. It is probable that the bed of lignite which is mined at the Brady mine, in sec. 6 of the township to the south, is present beneath part of sec. 31 of this township.

TPS. 22 AND 23 N., R. 15 E.

The surface from the south boundary of T. 22 N., R. 15 E., northward to the North Dakota line, may be characterized as a prairie across which Flat Creek meanders in a broad, open valley. The difference in elevation between the lowest and highest points in this area is scarcely more than 100 feet. The sandy loam soil has attracted a large number of farmers, and at the time the field was visited a large part of the area was under cultivation. All the area is within easy reach of the Chicago, Milwaukee & St. Paul Railway, which skirts the region along the North Dakota State line.

The lower part of the Lance formation, the Cannonball marine member of the Lance, and the Fort Union formation are present in these townships. The contacts are very obscure, both on account

of the similarity of the rocks and on account of the grass-covered condition of the surface.

A single bed of lignite in the Fort Union formation crops out in sec. 25, T. 23 N., and two sections were measured. At location 1018 the bed is 1 foot 5 inches thick, and at location 1019 it is 1 foot 1 inch thick.

TPS. 16 AND 17 N., R. 16 E.

Thunder Butte Creek, which meanders across T. 16 N., R. 16 E., from west to east in a very narrow channel several feet below the average valley level, drains practically the entire area of this township and T. 17 N., R. 16 E. A large part of the broad valley on both sides of the creek is nearly barren of vegetation, owing to the low fertility of the soil, but north of the creek the soft sandstone and sandy shale which occupy the uplands yield a sandy loam, and as a consequence the surface where not cultivated is grass-covered and rock exposures are scarce. Coal Springs, the only town in this area, is one of the older towns of the region. Grass covers the surface of these townships, but the cut banks of streams furnish numerous exposures from which the structure and character of the rocks were determined.

The Lance is the surface formation of this area. The line between the Ludlow lignitic member of the Lance and the underlying rocks is extremely difficult to follow, but by a study of the soil, which in areas of the Ludlow is more sandy and yellowish than in areas where the somber-colored clay shale of the lower part of the formation occurs, the contact between the two parts of the formation can be determined.

The only exposure of lignite is in sec. 24, T. 17 N., where a thin bed crops out in the side of the valley, with the following section:

Section of lignite bed at location 1020 in sec. 24, T. 17 N., R. 16 E.

	Ft.	in.
Shale, yellowish, sandy		8
Lignite, poor		2
Shale, carbonaceous		6
Lignite, poor		8
Shale, brown.		
Total section	2	0
Total lignite		10

TPS. 18 AND 19 N., R. 16 E.

Tps. 18 and 19 N., R. 16 E., occupy a position along the eastern edge of the Big Meadow. The western part of each township is almost level, but around the margin of the typical meadow area the surface is broken and numerous small streams have their beginning. In the portions of the townships which were originally occupied by meadow lands there are a large number of well-established farms with good buildings, windmills, etc., and only a few uncultivated

tracts remain. In this area, as in the rest of the meadow country, good wagon roads are to be found along nearly every section line. Meadow, one of the principal towns of Perkins County, is in sec. 13, T. 18 N., R. 15 E., and is the distributing point for all the eastern part of the county, being connected with the Chicago, Milwaukee & St. Paul Railway, 35 miles to the north, by daily automobile stage.

The upland is formed of rocks of the Ludlow lignitic member of the Lance formation, and exposures are exceedingly scarce. In the eastern part of these townships where the surface rocks belong to the lower part of the formation, exposures are more numerous than elsewhere. To judge from data collected in these and adjacent townships, the dip of the rocks is northward at about 15 feet to the mile.

Near the contact between the two members of the Lance there are at different localities one or more beds of lignite that have been mined on a small scale. Anderson mine, located at the "Coal Springs," in sec. 35, T. 17 N. (location 1021; see Pl. XI), is one of the oldest coal openings in northwestern South Dakota, but only a comparatively small amount of lignite has been mined and sold, probably owing to the fact that the bed is badly split by shale partings. Todd,[1] in 1902, visited this part of the region and measured a section of the bed. East of the Anderson mine, in sec. 36, T. 17 N. (section 1022, Pl. XI), there is a small strip pit from which some of the farmers mined coal for their own use in 1910–11, but the bed here is of little value.

The Cooke mine, at location 1025, in sec. 15, T. 17 N., is an open-strip pit from which considerable lignite was being mined and sold to the near-by farmers in 1911. The bed at this locality is separated into three thin benches by thick partings of shale. (See section 145, Pl. XI.) Along the side of the valley about a quarter of a mile north of the Cooke mine the upper bed is slightly thicker, containing at location 1024 1 foot 6 inches of lignite. At location 1026, in sec. 4, T. 17 N., a small amount of lignite had been removed by stripping from a bed 1 foot 11 inches thick.

In sec. 25, T. 18 N., R. 16 E., is a lignite bed, of which the following section was measured:

Section of lignite bed at location 1023, sec. 25, T. 18 N., R. 16 E.

	Ft.	in.
Lignite, top not exposed		9
Shale, carbonaceous		8
Lignite		5
Shale, brown.		
Total section	1	10
Total lignite	1	2

Other sections measured in these townships are shown graphically on Plate XI.

[1] Todd, J. E., South Dakota Geol. Survey Bull. 4, p. 50, 1910

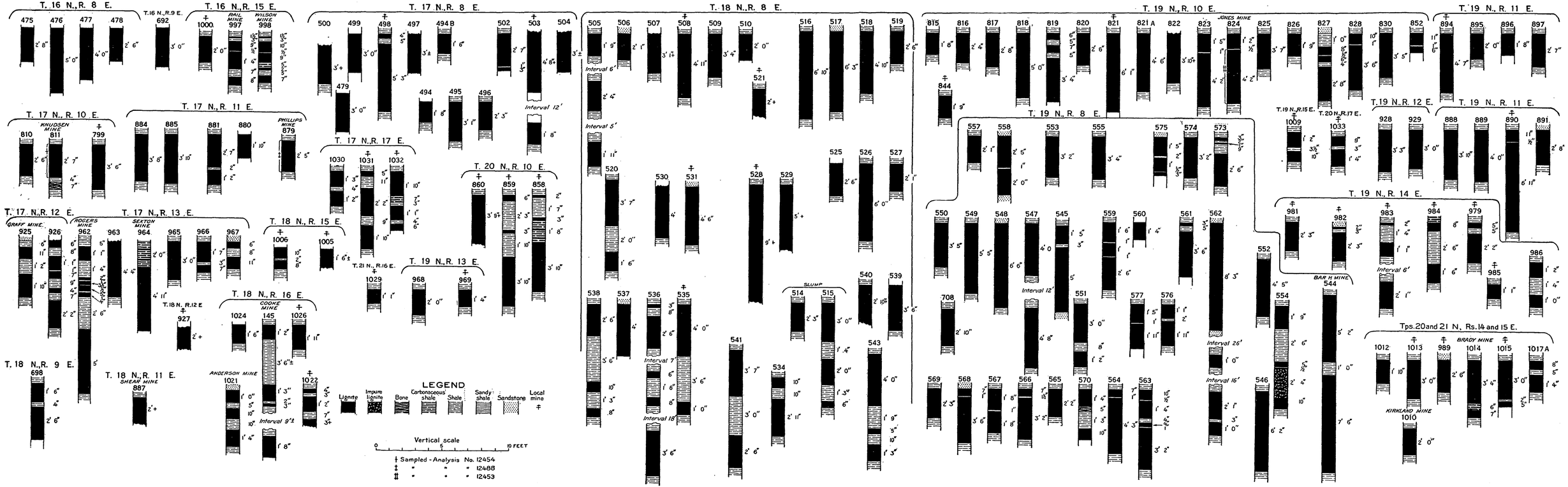
TPS. 20, 21, 22, AND 23 N., R. 16 E.

The area included in Tps. 20, 21, 22, and 23 N., R. 16 E., lies between the northern edge of the Big Meadow and the North Dakota State line and embraces a territory of more or less uniform topographic expression. The South Fork of Grand River, which flows from west to east across T. 21 N., occupies a comparatively narrow channel and receives the drainage from the entire area. To the south, the surface rises rather abruptly in rough badlands, so that an elevation of nearly 300 feet above the river level is reached in some places within a mile of the river bank. To the north, however, conditions are different. A terrace nearly 100 feet high rises very abruptly from the river, beyond which the surface is nearly level for a distance of more than a mile, and thence the altitude increases gradually until the maximum is reached at a distance of at least 10 miles from the river.

By far the greater portion of the area has been cultivated, and fairly good crops of small grains may be raised. Lemmon, the largest town in northwestern South Dakota (population 1,200), is on the north line of the State in secs. 20 and 21, T. 23 N., on the Chicago, Milwaukee & St. Paul Railway. Two important stage routes start from Lemmon, and as it is the only town on the railway in this region, it forms the shipping point for produce from nearly all of Perkins County as well as a considerable area in North Dakota. Excellent roads follow nearly every section line and connect all parts of the area.

Along the valley of Grand River the soft somber-colored shales of the lower part of the Lance formation are exposed at a number of places where recent erosion has dissected the surface. Within a short distance of the river the semibarren surface formed by these rocks is replaced by the grass-covered area in which the deep mantle of soil is the result of the disintegration of the sandy shale and soft sandstone of the overlying Ludlow lignitic member of the Lance. In the higher land north of the river the Cannonball marine member of the Lance and the Fort Union formation are the surface rocks, but the line between them is very obscure and its location is based mainly on topography.

Local lenses of lignite are exposed at two places near the top of the lower part of the Lance. At location 1028, in sec. 34, T. 21 N., R. 16 E., a bed 1 foot 6 inches thick is exposed near the main freight road between Lemmon and the country to the south. At location 1029 (see Pl. XI), in sec. 17 of the same township, a bed 1 foot 1 inch thick is exposed along the side of a small valley. At this point the overburden has been stripped in a small area and a few wagon loads of lignite have been removed for use among the farmers of the vicinity.



LIGNITE SECTIONS IN PERKINS AND HARDING COUNTIES, S. DAK.

In area examined by Dean E. Winchester.

At location 1027, in sec. 19, T. 20 N., the horizon at the top of the lower part of the Lance, at which, in many places, there are valuable lignite beds, is represented by 9 inches of lignite.

T. 17 N., R. 17 E.

The gently undulating, semibarren surface of T. 17 N., R. 17 E., is broken near the center by a series of low, flat-topped hills which rise more than 100 feet above the average altitude of this part of the field. Numerous farmers have settled in this township, in spite of the fact that soil derived from the clay shale does not make especially good farm land.

The Ludlow lignitic member of the Lance formation is exposed in the rather prominent hills near the center of the township, but the surface rock in the rest of the area belongs to the lower part of the Lance formation. A single lignite bed near the base of the Ludlow member is exposed at several places. A small drift mine at location 1032 (see Pl. XI), in sec. 16, known locally as the School Section mine, has been operated by the ranchers and farmers. Two drifts, each about 75 feet long, have been driven along the bed, but as the lignite has been mined by each ranchman for his own use no systematic development has taken place. A small strip mine was opened during the summer of 1911, at location 1031, in sec. 20, but at the time of examination only a small amount of lignite had been removed. Sections of the lignite beds exposed in this township are shown on Plate XI (locations 1030 to 1032).

TPS. 18, 19, 20, 21, 22, AND 23 N., R. 17 E.

In the area comprising the fractional townships along the eastern edge of the field the land south of South Fork of Grand River is semibarren, locally dissected into badlands by recent erosion, and therefore of little value for farming. However, a large number of settlers have taken up land in the area and their efforts to raise crops of small grains, potatoes, etc., are in some places being rewarded by success. North of the river the surface rises gradually in a more or less grass-covered country, traversed from north to south by two main open valleys. The soil in the lowlands area is derived from the clay shale of the Lance formation, but on the hills and slopes the overlying Ludlow lignitic and Cannonball marine members of the Lance and the Fort Union formation furnish the soil constituents and as a result the soil is sandy and more productive. In the upland area the mantle of soil is thick and there are practically no rock exposures from which to judge the bedrock conditions.

Lignite is exposed at only one place in the area (location 1033, in sec. 3, T. 21 N., R. 17 E.), and in October, 1911, the farmers of the

vicinity were mining lignite there for their own use. The bed, which has the following section, is near the top of the lower part of the Lance formation:

Section of lignite bed at location 1033, in sec. 3, T. 21 N., R. 17 E.

	Ft.	in.
Shale, sandy.		
Lignite		9
Shale, drab		3
Lignite	1	4
Shale, brown.		
Total section	2	4
Total lignite	2	1

BIBLIOGRAPHY.

The publications listed below contain discussions of the geology of the South Dakota lignite field.

Hayden, F. V., Notes explanatory of a map and section illustrating the geologic structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Philadelphia Acad. Sci. Proc., vol. 9, pp. 109–116, 1857. Gives map including the area, and in discussing the geologic age of the great lignite-bearing formation decides that it can not be older than Miocene.

Meek, F. B., and Hayden, F. V., Some remarks on the geology of the Black Hills and portions of the surrounding country: Philadelphia Acad. Sci. Proc., vol. 10, pp. 41–59 and map, 1858. Includes the northwestern part of South Dakota on geologic map as Tertiary.

Hayden, F. V., On the geology and natural history of the upper Missouri, being the substance of a report made to G. K. Warren: Am. Philos. Soc. Trans., vol. 12, new ser., pp. 1–219 and map, 1863. Discusses in this report the Great Lignite Tertiary Basin.

Cope, E. D., On the Cretaceous age of the lignites of the West: Philadelphia Acad. Sci. Proc., vol. 26, pp. 10–13, 1874. Discusses fossil and other evidence and decides that lignite-bearing beds of Dakota should be classified as Cretaceous.

Winchell, W. H., Report of a reconnaissance of the Black Hills of Dakota made by William Ludlow in 1874: U. S. A. Chief Eng. Rept., 1875, App., pp. 1131–1172. Describes occurrence of quartzite bowlders on the surface of the country west of Missouri River and discusses their origin.

Willis, Bailey, The lignites of the Great Sioux Reservation: U. S. Geol. Survey Bull 21, 1885. Describes area near Rabbit Butte and discusses origin of quartzite bowlders.

Todd, J. E., Recent geological work in South Dakota: Am. Geologist, vol. 16, p. 202, 1895. Mentions occurrence of White River and "Loup Fork" formations in Slim Buttes. Also mentions "disturbance in vicinity of Slim Buttes." States that the Laramie formation covers large areas in South Dakota and is lignite-bearing.

Todd, J. E., Loglike concretions and fossil shores: Am. Geologist, vol. 17, pp. 347–349, 1896. Discusses origin of loglike concretions.

Todd, J. E., The clay and stone resources of South Dakota: Eng. and Min. Jour., vol. 66, p. 371, 1898. Refers to sandstone in upper part of Laramie formation (so called) in Cave Hills.

Todd, J. E., A reconnaissance into northwestern South Dakota: South Dakota Geol. Survey Bull. 2, pp. 43–68, 1898. Describes geology of Harding and Perkins counties.

Darton, N. H., Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 497–599, 1901. Mentions "Loup Fork" and White River formations in northwest South Dakota.

Hatcher, J. B., Origin of the Oligocene and Miocene deposits of the Great Plains: Am. Philos. Soc. Proc., vol. 41, pp. 113–131, 1902.

Todd, J. E., Hydrographic history of South Dakota: Geol. Soc. America Bull., vol. 13, pp. 27–40, 1902. Brief discussion of orogenic movements and drainage history of northwest South Dakota.

Todd, J. E., Mineral building material, fuels, and waters of South Dakota, with production for 1900: South Dakota Geol. Survey Bull. 3, pp. 81–130, 1902. Mentions a lignite bed 10 feet thick on west side of Slim Buttes.

Todd, J. E., Geology of South Dakota; Am. Min. Cong., Sixth Ann. Sess., Rept. Proc., pp. 51–57, 1904. Gives short description of geology of northwestern South Dakota.

Leonard, A. G., The North Dakota-Montana lignite area: U. S. Geol. Survey Bull. 285, pp. 327–328, 1906. Reports lignite beds in different parts of field.

Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, p. 209 and map, 1905. Gives short description of geology of northwestern South Dakota, with geologic map of area.

Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, pp. 26–33, 1909. Gives short description of geology of northwestern South Dakota.

Knowlton, F. H., Stratigraphic relations and paleontology of the "Hell Creek beds," "Ceratops beds," and equivalents, and their relation to the Fort Union formation: Washington Acad. Sci. Proc., vol. 11, no. 3, pp. 179–238, 1909. Mentions dinosaur remains found in vicinity of Slim Buttes.

Stanton, T. W., The age and stratigraphic relations of the "Ceratops" beds of Wyoming and Montana: Washington Acad. Sci. Proc., vol. 11, No. 3, pp. 239–293, 1909.

Stanton, T. W., Fox Hills sandstone and Lance formation in South Dakota, North Dakota, and Wyoming: Am. Jour. Sci., 4th ser., vol. 30, p. 172, 1910. Speaks of evidence from northwestern South Dakota. Discusses age of these formations in North and South Dakota and Wyoming.

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, 193–207, 1910. Gives pictures of Rabbit Butte and section of lignite bed at Coal Springs and describes geology of Slim Buttes area.

O'Harra, C. C., Badland formation of South Dakota: South Dakota School of Mines Bull. 9, 1910. Gives short description of White River and Miocene formations of Perkins and Harding counties.

Knowlton, F. H., Further data on the stratigraphic position of the Lance formation ("Ceratops beds"): Jour. Geology, vol. 19, No. 4, pp. 358–376, 1911. Gives picture taken by Barnett of unconformity on Moreau River and discusses its importance as bearing on the age of the "Ceratops beds."

Perisho, E. C., The geology of Harding County, S. Dak.: Science, new ser., vol. 33, pp. 463–464, 1912. Gives short note on geologic features.

Winchester, D. E., Cross-bedding in the White River formation of northwestern South Dakota: Jour. Geology, vol. 21, No. 6, pp. 550–556, 1913. Describes cross-bedding in Slim Buttes.

Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, No. 6, pp. 523–547, 1915.

Knowlton, F. H., Cretaceous-Tertiary boundary in the Rocky Mountain region: Geol. Soc. America Bull., vol. 25, pp. 325–340, 1914.

Stanton, T. W., Boundary between Cretaceous and Tertiary in North America as indicated by stratigraphy and invertebrate faunas: Geol. Soc. America Bull., vol. 25, pp. 341–354, 1914.

INDEX.

A.

Page.

Acknowledgments to those aiding 8
Altitudes, data on 11
Anarchist Butte, geology at 30, 122
section at 29
Anderson, C. B., work of 8
Anderson mine, lignite of 161
lignite of, section of 162
Arikaree sandstone, character of 16, 34
fossils from 35
sections of 34–35
view of 32
Artesian water, lack of 13

B.

Badlands, location and character of 11
Bar H mine, lignite of 104
lignite of, section of 162
Bell lignite, location and character of 108
Bell mine, lignite in 108
lignite in, section of 124
Bibliography 164–165
Big Meadow, location and character of 10
Bison, description of 14
Bloom, section near 23
Bond lignite, location and character of 94, 96
Bond mine, lignite in 96
lignite in, section of 106
Brady mine, lignite of 158, 159
lignite of, section of 162
Breaks, The, location and character of 10, 127
Buffalo, description of 14

C.

Camp Crook, description of 14, 47
Cannonball marine member, character of 15, 16, 22–23
fossils from 25
section of 23
Cave Hills, geology of 27–28, 61, 77
lignite in 61–63, 69–74
location and character of 10, 61, 68
sections in 28, 69–70, 71
springs in 12–13
view of 10
Clark, B. W., work of 8
Clark mine, lignite of 94
lignite of, section of 106
See also Widow Clark coal.
Climate, character of 13
Coal lands, classification of 7
withdrawal of 7
Coaske, P. E., work of 7
Consolidated Coal Co.'s mine, lignite of 44
lignite of, analysis of 43

Page.

Cooke mine, lignite of 161
lignite of, section of 162
Cox mine, lignite in, section of 82
Craig lignite, location and character of 73
Craig mine, lignite in 73
lignite in, section of 82
Cretaceous system, description of 16, 17–18

D.

Dall, W. H., fossil determined by 34
Drainage, description of 11–12

F.

Faulting, occurrence of 36–37
Field party, personnel of 7–8
Field work, object and methods of 9–10
Fort Union formation, character of 16, 26–31
distribution of 26, 38
fossils from 31
lignite in .. 31, 39, 44–45, 131–132, 143, 144, 149, 160
analyses of 43
sections of 28–29
Fossils, determination of 18, 23–26, 31
Fox Hills sandstone, character of 16, 17–18
fossils from 18

G.

Geography, outline of 10–14
Geology, account of 14–38
map showing, Harding County .... In pocket.
Perkins County ..... In pocket.
Giannonatti lignite, location and character of 73, 78, 94, 107, 108, 109–110
Giannonatti mine, lignite in, section of 106
Gidley, J. W., fossils determined by 23, 33, 35
Gilmore, C. W., fossils determined by 33
Graff mine, lignite of 140
lignite of, section of 162
Grand River, description of 11
Green mine (T. 21 N., R. 8 E.), lignite in, section of 124
Green mine (T. 21 N., R. 9 E.), lignite in 124
lignite in, section of 124
Greene, S. D., work of 8

H.

Harding County, map of ..... In pocket.
sections in, plates showing ... 82, 92, 106, 124, 162
Hares, C. J., work of 8
Hilton mine, lignite of 44, 66–67
lignite of, analysis of 42
sections of 67, 92

J.

Page.
J B Hill, location and character of..... 99
Jones mine, lignite of..... 39, 44, 127, 128, 135
lignite of, analysis of..... 42
sections of..... 128, 162
view of..... 44
Jump-off, location and character of..... 11, 55, 59

K.

Kirkland mine, lignite of..... 158
lignite of, section of..... 162
Knowlton, F. H., fossils determined by. 23, 25-26, 31
Knudsen mine, lignite of..... 44, 125-126, 127
lignite of, analysis of..... 42
sections of..... 125, 162
view of..... 44

L.

Lance formation, age of..... 26
character of..... 15-16, 18-23
fossils from..... 23-26
lignite in..... 22, 38-39, 44, 46-164
analyses of..... 42
stratigraphy of..... 15
figures showing..... 15
view of..... 32
See also Cannonball member; Ludlow member.
Land survey, monuments of..... 9
Lemmon, description of..... 14, 162
Lignite, analyses of..... 40-45
burning of..... 39
character of..... 39-40
consumption of..... 45-46
distribution of..... 7, 38-39
occurrence of, by townships..... 46-164
tonnage of..... 46
use of..... 45-46
Literature, list of..... 164-165
Little Missouri River, description of..... 11
Lloyd, E. R., work of..... 8
Lodgepole, section near..... 28
Lodgepole Buttes, geology of..... 28-30, 122
lignite in..... 110, 123
location and character of..... 109, 121
sections near..... 28-29
springs in..... 12-13, 122
L ranch, springs near..... 12, 101
Ludlow lignitic member, character of.. 15-16, 19-22
fossils from..... 24-25
lignite of..... 22, 38-39, 44
analyses of..... 42
sections of..... 20-22

M.

Map, geologic, Harding County.....In pocket.
Perkins County.....In pocket.
Map, index..... 8
Meadow, description of..... 14, 156
Mendenhall prospect, lignite of..... 44
lignite of, analyses of..... 42
sections of..... 85
Moreau River, description of..... 11-12

N.

Page.
Nelson mine, lignite of..... 44, 143
lignite of, analysis of..... 43
section of..... 154
Neuman, L. M., work of..... 8
Newcomb mine, lignite of..... 44, 119
lignite of, analysis of..... 42
section of..... 124
Nipper & Monroe mine, lignite of..... 44
lignite of, analysis of..... 43
North Dakota, lignite from, analyses of..... 43

O.

Olson mine, lignite in..... 119
lignite in, section of..... 124

P.

Parks, E. M., work of..... 7, 8
Pelham mine, lignite of, section of..... 82
Perkins County, map of.....In pocket.
sections in, plates showing..... 154, 162
Phillips mine, lignite of..... 39, 44, 134
lignite of, analysis of..... 42
section of..... 162
Pierre shale, character of..... 16, 17

Q.

Quaternary system, character of..... 35-36

R.

Rabbit Butte, lignite in..... 145
lignite in, section of..... 145
Rail mine, lignite of..... 154
lignite of, sections of..... 154, 162
Railways, routes of..... 14
Reclamation Service mine, lignite of..... 44
lignite of, analysis of..... 43
Reeside, J. B., jr., work of..... 8
Reptilian remains, determination of..... 23, 26
Riggs, R. J., work of..... 7
Riley lignite, location and character of..... 73
Riley mine, lignite of, section of..... 82
Roark, L. R. work of..... 8
Robinson, H. M., work of..... 7
Rogers mine, lignite of..... 146
lignite of, section S. of..... 162
St. Clair, Stuart, work of..... 8
School Section mine, lignite of..... 163
Scranton mine, lignite of..... 44
lignite of, analysis of..... 43
Section, general, in northwestern South Dakota..... 16
Settlement, progress of..... 14
Sexton mine, lignite of..... 146
lignite of, section of..... 162
Shear mine, lignite of..... 135
lignite of, section of..... 162
Sheep Mountain, geology at..... 112
Shirley mine, lignite at..... 109
lignite at, sections of..... 108, 124
Short Pine Hills, location and character of. 10, 54-55
section in..... 32, 35

Page.
Slim Buttes, geology in and near 30, 34, 85–86, 99, 103, 112–113
landslide at 103–104
views of 10, 32
lignite in 83, 86, 90, 102–103, 104
sections of 83–85, 87, 88, 89, 90, 103
location and character of 10, 84, 98–99, 103, 112
sections in 32
springs at 12, 87
view of 32
South Cave Hills. *See* Cave Hills.
Springs, distribution of 12–13
See also particular townships.
Stanton, T. W., fossils determined by 23
Stratigraphy, account of 14–36
figures showing 15
Stream robbery, chances for 12
Strool, description of 14
geology near 30
Structure, description of 36–38
map showing 37

T.

Table Mountain, location and character of ... 63
section of 75
T Cross lignite, location and character of 73, 75
Tepee Buttes, location and character of 95
Tertiary system 16, 18–35
Thom, W. T., jr., work of 8
Thunder Butte Creek, description of 160
lignite on, section of 150
Timber, distribution of 13
Todd, J. E., reconnaissance by 8–9
Townships, list of. *See* Contents, pp. 3–6.

V.

Van Emon, W. C., work of 8
Vegetation, character of 13

W.

Washburn Lignite Coal Co.'s mine, lignite of. 44
lignite of, analysis of 43
Water supply, sources of 12–13
White River formation, character of 16, 32–33
fossils from 33–34
landslide in, view of 10
sections of 32
views of 10, 32
Widow Clark lignite, location and character of 77, 94, 106, 108
Willett, pumping at 13
Wilson mine, lignite of 156
lignite of, sections of 155–156, 162
Winchell, N. H., explorations by 8
Winchester, D. E., work of 8
Woodruff, E. G., work of 8