nd Irrigation Paper No. 117

Series { A, Economic Geology, 45
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DEPARTMENT OF THE INTERIOR

ITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GNITE OF NORTH DAKOTA

AND ITS RELATION TO IRRIGATION

BY

F. A. WILDER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States, folios and separate sheets thereof; (8) Geologic Atlas of United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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The following Water-Supply Papers are out of stock, and can no longer be supplied: Nos. 1-16, 19, 20, 22, 29-34, 36, 39, 40, 43, 46, 57-65, 75. Complete lists of papers relating to water supply and allied subjects follow. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

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WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.
WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.
WS 117. The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. 1905. 59 pp., 8 pls.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Part II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Part III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by J. B. Lippincott. 1902. 100 pp., 32 pls.
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WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.
WS 89. Water resources of Salinas Valley, California, by Homer Hamlin. 1904. 91 pp., 12 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.
WS 116. Water resources of Santa Barbara, Cal., by J. B. Lippincott. 1905. —— pp., 8 pls.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Part IV.

[Continued on third page of cover.]

Water-Supply and Irrigation Paper No. 117

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

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THE LIGNITE OF NORTH DAKOTA

AND ITS RELATION TO IRRIGATION

Water Resources Branch,
Geological Survey,
Box 3106, Capitol Station
Oklahoma City, Okla.

BY

F. A. WILDER

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., June 18, 1904.

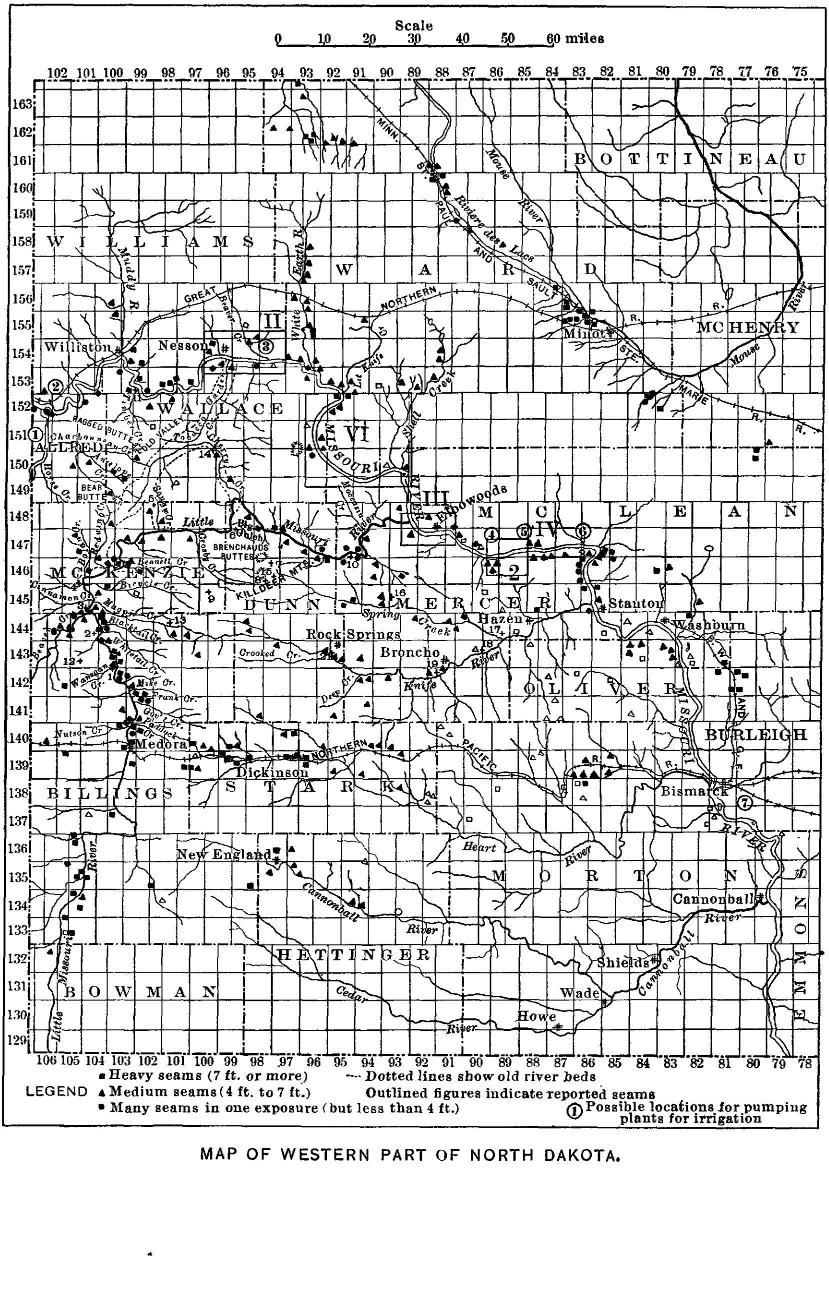
SIR: I have the honor to transmit herewith a report by Prof. F. A. Wilder on the lignite of North Dakota and its relation to irrigation, and recommend that it be published in the series of Water-Supply and Irrigation Papers.

The investigation on which this report was based was carried on under the charge of Mr. N. H. Darton as a part of the general investigation of the underground-water resources of the western portion of the United States. It is thought that the information contained in the paper will be of interest in connection with the underground-water resources of North Dakota.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.



MAP OF WESTERN PART OF NORTH DAKOTA.

THE LIGNITE OF NORTH DAKOTA AND ITS RELATION TO IRRIGATION.

By F. A. Wilder.

INTRODUCTION.

The areas most favorably situated for irrigation in North Dakota are the broad terraces along the Missouri and its tributaries. These streams are deeply intrenched, and it does not seem possible by means now available to raise water from them a vertical distance of from 150 to 400 feet over the bluffs that rather sharply bound the broad valleys.

When the Yellowstone enters the State it has a fall per mile of only 2.7 feet, while the Missouri's gradient for an equal distance is about 2 feet. A fall of 1 foot per mile is necessary to carry water in an irrigating ditch, so that to raise water 40 feet above the Missouri would require a ditch 40 miles long. The tributaries of the Missouri have gradients somewhat higher, but the flats along them are cut up by the meandering of the streams, and conditions are not favorable for long lateral ditches or extensive reservoirs.

On account of the fertile terraces in the valleys of the streams, ranging from 15 to 100 feet in elevation above water level, and the abundance of lignite along them, it seemed desirable to consider the possibility of irrigating the 250,000 acres included in the stream terraces by pumping from the rivers directly, using lignite as fuel. The lignite area, therefore, has been studied, and the nature of the lignite beds investigated. Practical tests have been made to determine the value of this material as fuel for generating steam, and computations have been made to ascertain, at least in a rough way, the cost of irrigating river flats which are less than 100 feet above the streams. The Missouri and its tributaries in North Dakota have been followed, and the extent and elevation of the river flats and the amount and quality of the lignite near them have been noted.

If only a small fraction of the western part of the State is under irrigation, the productiveness of the whole region will be greatly increased. Every river valley contains land which may be considered with reference to irrigation possibilities. With a few acres which can be watered at will, and abundant range for cattle in the broken or rolling land back of the valley, ten families, by combining farming with cattle raising, will prosper where one finds a living now. These conditions will lay a sure foundation for the dairying industry, which should be one of the foremost of the State.

LIGNITE AREA IN NORTH DAKOTA.

While thin beds of lignite have been recognized in the eastern part of the State and have been previously described,[a] the only workable beds east of the center of the State are in the Turtle Mountains and at the southern bend of the Sheyenne River, about 25 miles southeast of Valley City, the Turtle Mountains being an outlier of the lignite area proper. The region in which lignite may reasonably be expected to be found, and which is discussed in this bulletin, may be roughly bounded on the east by a line beginning at the northern boundary of the State, 30 miles east of the Minneapolis, St. Paul and Sault Ste. Marie Railway, and extending southeast to Harvey, thence south through Steele to the southern boundary. More careful study, aided by well borings, which will doubtless be made as the country is settled, will perhaps shift this line at certain points 30 or 40 miles east or west. On the north, south, and west the lignite continues beyond the boundaries of the State. This region is of very great extent, having an area equal to half of that of the State of Ohio.

It is highly probable that lignite does not exist in beds of workable thickness in every part of this region, but it is equally probable that the fraction of the area lacking lignite in beds of three or more feet in thickness is a small one, not more than one-fifth of the whole. In the southeastern portion of the area, about the lower part of Cannonball River, thick beds seem to be lacking. Where heavy beds are present, all may not be available, either on account of depth or some difficulty in mining, and throughout the eastern portion of the region they are so thoroughly concealed by glacial drift that without a knowledge of the underlying formations and of the surrounding country their existence would be unsuspected.

The restriction of the term lignite area to the region in which workable beds of lignite are found greatly simplifies the stratigraphic series and limits this section to a consideration of the Laramie and the glacial drift.

The Laramie, which is the latest stage of the Cretaceous, contains all of the workable lignite in North Dakotá. Early students of the field referred part of the lignite beds to the "Fort Union" on paleontologic grounds. Reasons for retaining the distinction have not

[a] Upham, Warren, The glacial Lake Agassiz: Mon. U. S. Geol. Survey, vol. 25, 1895, p. 92.

seemed adequate, and the effort may well be abandoned. The Laramie is found over the region previously outlined as the lignite area, though its eastern border is buried, often deeply, by glacial drift. The difference in elevation of its deposits actually exposed within the State is at least 1,400 feet. Its greatest thickness, shown with certainty by the well at Medora to be more than 2,000 feet, occurs in the western part of the State, while its vertical extent gradually decreases toward the east till at the edge of the Coteau du Missouri it drops off sharply, beyond which it continues as a relatively thin series. The Laramie consists of clays, sands, sandstone, lignite, and thin bands of hematite, clay ironstone, and shaly limestone.

OCCURRENCE OF THE LIGNITE.

The numerous natural exposures of lignite in the driftless area and the remarkably fine opportunity to study the Laramie strata given by the badlands make it possible to draw, even from a preliminary study of the region, rather far-reaching conclusions in regard to the nature of the lignite beds. Five well-developed beds outcrop in the bluffs of the Little Missouri at Medora and may be traced for miles both north and south of this point. Along the Missouri south of Williston five or six beds show in a single section and can be traced for long distances, while on the Fort Berthold Reservation nine well-developed beds occur in a single exposure. The wells at Medora and Dickinson, a record of which is given in fig. 1, show an even greater number of beds. Near the eastern edge of the lignite area the number of beds is greatly reduced, but even here two or three exist at certain points, though generally but one is workable.

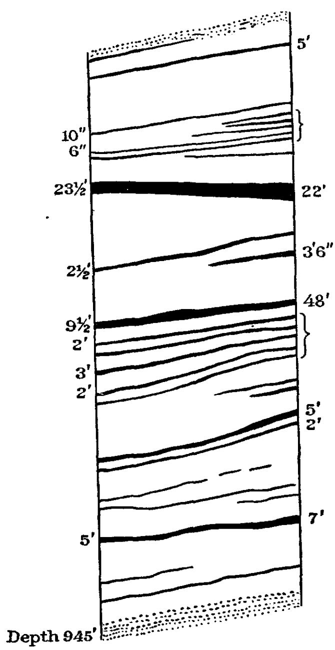


FIG. 1.—Diagram of lignite beds between Medora and Dickinson, N. Dak., by N. H. Darton.

On account of the nature of the beds, considered in a later paragraph, their number does not remain constant through large areas, and it is possible, though hardly probable, that at a few localities in the heart of the lignite area a prospect hole might pass completely through the Laramie, and not encounter a single lignite bed. This variation in number and thickness of beds, often within comparatively short distances, will be a factor of great practical importance in opening up on a large scale a new lignite field. In the first place, it will increase the number of prospect holes that must be sunk to determine the amount of available coal in a given area. To offset this, however, are a number of conditions which make prospecting unusually easy.

Thickness of beds.—The lignite beds in North Dakota vary in thickness from an inch to 40 feet. This maximum thickness, which was carefully measured in the summer of 1902, occurs at an outcrop in sec. 31, T. 135, R. 101, which will be described in connection with the lignite on Little Missouri River. Three beds that reach a thickness of 25 feet are known, while beds 15 feet thick are not uncommon. In the western part of the State beds 2 and 3 feet thick are so common that in this report it is not practicable to note them minutely.

Extent of beds.—As important from an economic point of view as their thickness is the question of their persistence laterally. Attention was directed to this point, and the elevation of beds was noted in order to correlate, if possible, the beds exposed at one point with those at another. Generally such a correlation of beds distant from one another a number of miles was impossible on account of variations in thickness and elevation. While a single bed was often traced for 5 or 6 miles along the banks of the Little Missouri, another seen at the same time might thin out and give place to others above or below. The interrupted bed might begin again farther on after a break of half a mile or more, the lignite meanwhile being replaced by a bituminous or a nearly pure clay. The deduction, which early in the work seemed true, that certain horizons in the Laramie are much richer in lignite than others was not borne out by later observations. For a given locality the statement holds good, but a horizon which abounds in lignite at one point may be barren in another. A striking instance of the rapid thinning out of a bed is given by the 40-foot bed already referred to, which within one-fourth of a mile decreases to 17 feet, the top and bottom drawing together like the surfaces of a lense. Sufficient work has been done at one point near Minot to demonstrate the persistence of a thick bed beneath the greater part of a township, but this seems to be the exception rather than the rule. N. H. Darton has suggested a correlation of the beds encountered in the wells at Medora and Dickinson, but as the distance between these points is 39 miles, and lignite beds vary so greatly in order and continuity, the identity of the beds can not be established.

Variations in fuel value in a single bed.—A majority of the beds examined and tested show no great difference in fuel value from top to bottom. In some instances, however, the differences in the composition of the lignite in a given bed are considerable. Not infrequently the upper foot or two are inferior, and are left for roof in mining. The loss in this case is not as great as might be expected, for it is often more economical to leave coal for a roof than to timber. When the lignite lies directly under the glacial drift, as at the Hanchett mine, 10 miles southwest of Velva, the upper portion shows deterioration. Shaly layers sometimes occur, which if mixed with the coal from the rest of the bed raise the percentage of ash for the whole very considerably. Sulphur in any form is present commonly only in traces. Iron nodules, which prove so annoying to the operator of mining machines in the East, do not occur in the lignite, and there are no hindrances to the use of drills and undercutting machinery.

Variations in fuel value in different beds.—The chemical analyses of 70 samples from as many beds, given on pages 17 and 18, throw light on the fuel value of lignites from as many parts of the State. Samples were not taken from beds that were obviously too thin or too impure to be of economic value, but, on the other hand, all analyses made are given, whether favorable to the lignite or not. The lignites taken as a whole will probably average better than the samples analyzed indicate, for in many cases fresh material could not be obtained, and the weathering on the surface of a natural exposure is sufficient to lessen the carbon values for some feet from the surface. In the discussion which follows, lignites which are reported as good have between 40 and 50 per cent of fixed carbon and not more than 8 per cent of ash.

Possibilities of coal at greater depths.—There are no theoretical considerations to support the rather common notion that at greater depths a higher grade of coal exists. The analyses of the coals found by the railroads in the deep drillings in the western part of the State have not been examined, but as these borings were made some years ago and no development work has followed, the inference seems fair that bituminous coal in significant quantities was not found.

A popular fallacy in regard to lignite.—The belief so often expressed that lignite beds outcropping on slopes are certain to thicken is hard to account for. While in many cases the beds doubtless thicken away from the outcrop, the reverse will as often prove true. The lignite beds being in general lens-like, it is impossible without drilling to determine whether the outcrop represents a section near the edge of the lens or across the center. If the outcrop represents a section near the edge of the lens the lignite will thicken as the drift goes into the hill or bank till the center of the lens is reached, while if it is across the center the lignite will become thinner.

OUTPUT OF LIGNITE IN 1902.

Following is a summary of the output of the lignite of North Dakota mines in 1902:

Summary, by counties, of lignite output for 1902.

County.	Loaded at mine for shipment.	Sold to local trade.	Total product.	Total value.	Average spot value per ton.
	Short tons.	*Short tons.*	*Short tons.*		
Billings	----------	5,000	5,000	$4,000	$0.80
Burleigh	120,000	10,000	130,000	169,000	1.30
Emmons	----------	1,000	1,000	2,750	2.75
Mercer	----------	3,000	3,000	2,400	.80
Morton	30,000	5,000	35,000	45,000	1.30
McLean	----------	4,000	4,000	5,200	1.30
Oliver	----------	3,000	3,000	2,400	.80
Stark	45,000	10,000	55,000	66,000	1.20
Ward	57,800	19,000	76,800	107,520	1.40
Williams	----------	3,000	3,000	24,000	.80
Total	----------	--------	315,800	428,270	

FUEL VALUE OF NORTH DAKOTA LIGNITE.

The fuel value of a given lignite will vary considerably with the conditions under which, and the purpose for which, it is used. In one connection it may be esteemed highly and in another have no value at all. Out of this fact grows the diversity of opinion in regard to a number of well-known lignites of the State. A lignite whose value as a steam coal is very high may not prove suitable for certain kinds of stoves. An actual case will serve well for illustration. In two localities lignite from seams that are high in ash, due to admixture of clay, are highly valued for heating purposes, because the clay enables them to stand up well and prevents slacking. Judged by ordinary standards these lignites are very inferior. These recognized standards are: The amount of fixed carbon and the percentage of ash that the lignite contains, the result given by the calorimeter, and the amount of water that a given amount of lignite will evaporate. Of the three tests the last is the most satisfactory. The lignites have been tested in accordance with these, as well as in a variety of practical ways, and a brief statement of results is appended.

LABORATORY TESTS.

CHEMICAL PROPERTIES OF LIGNITE.

Fixed carbon.—The average amount of fixed carbon in 26 samples of North Dakota lignite analyzed in 1900, when thoroughly dried, was 52 per cent. Sixty samples, after thorough drying, gave 51.21 per cent of fixed carbon. Compilations of analyses of 41 samples of West Virginia bituminous coal show 67.16 per cent of fixed carbon; 22 samples of the better grades of semibituminous dry coals of Maryland show 75.99 per cent; and 26 samples of dry bituminous coal from Pennsylvania show 67.97 per cent. Judged by the fixed carbon alone the heating power of North Dakota lignite is 76 per cent of that of West Virginia bituminous, 65.9 per cent of that of Maryland semibituminous, and 74.4 per cent of that of Pennsylvania bituminous. These figures show that the North Dakota lignites rank far above the coals that are the average representatives of this class.

With respect to fixed carbon, the lignite of North Dakota appears to be equal to the product of the Western Interior coal field (which includes Iowa, Missouri, and Kansas). According to a recent United States Geological Survey report,[a] the amount of fixed carbon in 12 samples from the Western Interior field, computed on a dry basis, averages about 50 per cent. These coals, however, have a somewhat higher evaporative power than the lignites.

Volatile matter.—The average amount of volatile matter, exclusive of water, computed from 60 analyses of different lignite coals, is 35.63 per cent. When the fixed carbon alone is considered as determining the fuel value of a coal the worth of the volatile matter is overlooked. Under proper conditions these gases may be made to develop a great deal of heat, and no appliances which aim at an economical combustion of lignite can afford to disregard them.

Ash.—The percentage of ash in the 60 samples is generally low, the average amounting to 8.5 per cent. By deducting 4 inferior samples, the average will be lowered to 7.5 per cent. Compared with coals of the Iowa, Missouri, and Kansas region, lignites are notably purer. In the ash from some North Dakota coals there is a tendency to form clinkers, due to the presence of clay, but generally the lignite burns like wood, leaving a gray powdery residue.

Sulphur.—The percentage of sulphur in the lignites is usually

[a] Bain, H. Foster, Western Interior coal field: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 333-366.

low—much lower than in most bituminous coals. The following samples are fairly representative:

Percentage of sulphur in North Dakota lignites.

	Per cent.
Lehigh mine	0.88
Washburn mine	.91
Forty-foot vein, Billings County	1.10
Electric mine, Kenmare	.68
Davis mine (Mouse River Lignite Company)	.35

The sulphur in these analyses was determined in dry coal, which brings the percentage one-fourth higher than for lignite fresh from the mine. A yellow powder composed of calcium sulphate and iron oxide often occurs in the upper part of lignite seams and in color and texture resembles sulphur.

The average of 60 tests shows that the lignite contains 35.66 per cent of volatile matter and about 30 per cent of moisture. Several service tests of lignite show it to have an evaporative power of 4.2 pounds of water from and at 212° F. per pound of fuel. This amount is below the average test, but it is the amount used in computations for fuel value, and is 75 per cent of that of Iowa coal and 70 per cent of that of the Missouri product.

PHYSICAL PROPERTIES OF LIGNITE.

Moisture.—In a far larger measure than is the case with bituminous coal, the physical properties of lignite must be kept in mind in considering its fuel value. A series of analyses subsequently quoted shows that lignite fresh from the mine contains 30 per cent of moisture, in which respect samples taken from various parts of the State differ but slightly. When shipped under ordinary conditions and in the usual manner, the lignite reaches the engine room with nearly all of its moisture. Small samples that are more or less exposed to the air for two months reach the laboratory with from 10 to 20 per cent of moisture, as shown by the following tables, which give analyses of specimens in which no special effort was made to prevent drying.

The expense of shipping this moisture and its effect on the heating properties of the lignite are points worthy of careful study and experiment. The general opinion of those burning lignite is that if the lignite, in drying, did not fall to pieces, becoming so fine that it was apt to go through the grates, there would be great economy in burning it after drying, and that in those devices where powdered or fine coal is used the dry lignite presents a material saving over the "green." Theoretically, it would seem that this should be the case, for the heat necessary to volatilize the 30 per cent of moisture would be saved, and there is no apparent reason for a material loss of the volatile gases in drying.

In any case, if the coal could be dried before shipping and economically burned after drying, the freight charges would be reduced nearly one-third.

The so-called slacking of lignite is the process of crumbling that it undergoes when drying. It probably loses none of its fuel value in consequence, and there is probably a gain in this respect due to the absence of the moisture. Special conditions are necessary, however, to burn this fine coal advantageously, the danger being that it will fall through the grate or be blown out through the stack.

ANALYSES OF SAMPLES OF LIGNITE.

Analyses of lignite fresh from mine.

[Fixed carbon, volatile matter, and ash computed on dry basis.]

Mine and location.	Fixed carbon.	Volatile matter.	Ash.	Moisture.
Mouse River Lignite Co., Burlington:				
4 feet from bottom	51.28	35.83	11.89	32.00
Top	46.42	32.60	20.98	30.00
16 inches above clay seam	47.36	42.14	10.50	29.40
Lower 20 inches	52.96	38.93	8.11	34.70
Electric mine, Kenmare:				
4 feet from floor	57.95	34.41	7.64	32.90
3 feet from floor	59.19	36.56	4.25	35.00
Bottom	56.58	34.44	6.98	34.80
Top	56.87	36.58	6.55	34.80
Diamond mine, Kenmare:				
Top	52.98	37.24	9.78	33.00
Center	56.82	33.77	9.41	33.00
Lower 18 inches	56.97	36.28	6.75	33.60
Dakota Lignite and Brick Co., near Burlington	55.61	40.08	4.30	23.40
New Era mine, near Minot	57.66	38.22	4.12	33.60
Smith-Kenmare Dry Coal Co.:				
Next to clay	55.55	36.79	7.67	33.20
Next to roof	52.30	39.90	7.80	32.00
1 foot below roof	55.25	33.50	11.25	32.60
Wadeson mine, Sims	50.47	39.21	10.32	30.29
Lehigh mine	51.62	43.18	5.21	34.30
Satterlund mine, near Washburn	55.89	37.50	6.61	30.91
Washburn mine, at Wilton	54.93	38.75	6.32	31.82
Dickinson Brick Co	46.89	38.23	14.88	27.82
On Heart River, near Dickinson	60.49	38.31	1.20	14.25
Consolidated Coal Co., New Salem	53.86	41.66	4.48	27.48

Analyses of lignite partly dried.

[Fixed carbon, volatile matter, and ash computed on dry basis.]

Mine and location.	Fixed carbon.	Volatile matter.	Ash.	Moisture.
Sample from Beaver Creek, E. Williams County	57.97	38.34	3.69	18.13
Sample from Dry Fork Creek	48.99	35.81	15.19	16.26
Outcrops near agency at Elbowoods	57.29	37.29	4.76	19.97
Ed Hall's mine, near Fort Berthold Agency	51.41	35.16	13.43	17.63
Anderson mine, Stanley	50.95	38.40	16.65	20.36
Jones mine, 16 miles southwest of Balfour	53.77	37.72	8.51	21.73
Missouri River, west of White Earth River	51.60	43.04	5.36	13.33
Rose Hill mine, 15 miles southwest of Balfour	53.11	38.81	8.08	18.08
Opening, 8 miles north of White Earth	56.51	36.94	6.55	17.76
F. F. Alger mine, Stanley, Ward County	49.63	35.57	14.80	16.80
Pleasant Valley mine, Shell Creek	55.09	39.89	5.02	17.06
Sikes mine on the Little Knife	47.55	42.68	9.77	16.03
Badlands, 6 miles east of Fort Berthold	47.38	42.75	9.87	14.64
Boyds mine, sec. 17, T. 152, R. 94	55.18	37.85	6.97	17.63
Nesson opening	60.38	36.09	3.53	19.97
Williams opening, 5 miles south of White Earth	44.49	31.59	23.92	17.02
Gille-Miller mine	60.12	34.19	5.69	18.39
Sorenson mine, sec. 32, T. 162, R. 92	60.95	34.12	4.93	19.42
Pony Gulch mine, 16 miles southwest of Harvey	51.66	36.72	11.62	19.16
Leigh Ericson, Donnybrook	59.75	35.14	5.11	19.50
Lloyd Mining Co	58.23	33.13	8.64	17.08
Scribner's mine	56.61	36.87	12.52	16.23
Drift, near railroad bridge near Burlington	56.57	38.01	5.42	17.46
Turtle Gulch mine, sec. 14, T. 152, R. 81	53.78	37.20	9.02	20.02
Wm. Lacy's land, Coal Harbor	53.43	39.14	7.43	18.51
Hanchett mine, southwest of Velva	53.60	40.14	6.16	16.69
Coal Canyon, 30 miles south of Medora	52.47	38.57	8.96	16.79
J. C. Gamel's ranch, sec. 20, T. 133, R. 104	55.90	37.59	6.51	18.24
Sentinel Butte, Billings County	48.04	42.67	9.29	18.99
From 777 ranch on Little Missouri	43.47	34.55	21.98	14.54
Forty-foot seam, sec. 31, T. 135, R. 101	51.79	38.69	9.52	13.70
Lower vein on Missouri River, 3 miles south of Williston	50.65	36.15	13.20	10.56
Twelve-foot seam, 3 miles east of Williston	54.38	36.37	9.15	11.25
Heaton's land, sec. 29, T. 145, R. 80	54.59	39.49	5.92	11.04
Coal Lake mine, sec. 22, T. 146, R. 82	55.73	38.74	5.53	11.23
Reiss mine, New England	53.03	38.39	8.58	24.46
Stone-Bird mine, near Belfield	56.61	35.71	7.68	21.56
Average	51.21	35.63	8.50	--------

Number of samples in Tables I and II, 60.

Deductions.—The method of analysis employed differs from that commonly used for lignites, for the percentage of moisture is first computed and then, after the moisture has been expelled, the amount of the other constituents is determined. The percentage of fixed carbon, volatile matter, and ash is made somewhat higher than when the undried coal is analyzed. The practical difficulty in bringing the lignite to the laboratory without partly drying, however, makes it much more desirable to compute composition on a dry basis.

Even when allowance is made for this method of computation the percentage of fixed carbon is high enough, if this alone is considered, to remove these coals from the lignites and place them with the semi-bituminous or steam coals. The content of water, however, about 30 per cent, keeps them in the former class.

PRACTICAL USE.

EVAPORATIVE TESTS.

More satisfactory than either chemical or calorimetric tests are practical evaporative tests carried on with boilers of standard patterns. A number of such tests have been made, and in some cases eastern coal also has been tested in the same boilers and under practically the same conditions, so that, knowing the price of each coal at the point given, it is possible to determine definitely the economy resulting from use of lignite.

Tests under natural draft.—The following test was made at the asylum for the insane at Jamestown by Chief Engineer Thomas Pettigrew, whose careful study of proper methods for burning lignite has greatly advanced the lignite industry.

Test of lignite at insane asylum at Jamestown, N. Dak.

[Date of test: Youghiogheny coal, August 6, 1894; lignite coal, August 8, 1894.]

	Youghiogheny coal.	Lignite coal.
Duration of test .... hours..	7½	8
Average temperature of feed water .... ° F..	74	74
Coal burned .... pounds..	1,400	3,370
Combustible .... do....	1,243	3,170
Ash .... per cent..	11.21	5.93
Coal burned per square foot of grate per hour .... pounds..	8.29	18.72
Total water evaporated at temperature of feed .... do....	8,837	14,157
Water evaporated in pounds per pound of coal actual condition	6.312	4.2
Water evaporated per pound of combustible .... pounds..	7.1	4.46
Temperature of flue gases .... ° F..	510	510
Boiler 6 feet in diameter by 16 feet long, with 30 4½-inch flues; grate surface, 4 feet 5 inches by 5 feet; coal 3 days from mine; value of coal	$1.00	$0.665

The cost of Youghiogheny lump at Jamestown was $6.80 per ton and of lignite $2.80.

Test of Lehigh lignite made by the Missouri Valley Milling Company at Mandan, N. Dak.

Duration of test	hours	11
Kind of furnace		Smith-White.
Grate surface	square feet	30
Width of air space in grate	inch	$\frac{1}{4}$
Water-heating surface	square feet	1,549
Ratio of water-heating surface to grate surface		51 to 1
Average steam pressure		104
Average temperature of feed water entering boiler	° F	175
Total coal fed to furnace	pounds	12,221
Moisture in coal	per cent	23
Coal consumed per square foot of grate per hour	pounds	37
Cost of coal delivered at mill per ton		$1.60
Total cost of coal		$9.77
Total weight of water fed to boiler	pounds	56,350
Water evaporated per hour from and at 212° F	do	5,554
Horsepower developed		163
Cost of fuel for evaporating 1,000 pounds of water		$0.1734
Average horsepower of engine		190
Cost per horsepower per hour		$0.0047

The mill has a capacity of 450 barrels of flour per day, and the cost of fuel, when lignite is burned, per barrel of flour ground is 4.46 cents.

Test of Wilton lignite coal in the Fargo-Edison Company's plant at Fargo, N. Dak., January 9, 1901.

Duration of test	hours	12
Boilers used: Two 16 feet by 72 inches tubular, one 200-horsepower Heine water tube.		
Total heating surface	square feet	4,823
Total grate surface	do	88
Average steam pressure	pounds	83
Average temperature of feed water	°F	140
Total weight of coal fired	pounds	26,400
Cost of coal per ton of 2,000 pounds at boilers		$2.60
Total cost of coal		$34.32
Total weight of water pumped into boilers and apparently evaporated	pounds	97,500
Water evaporated per pound of coal from average pressure and temperature	pounds	3.7
Equivalent evaporation from and at 212° F	do	4.1
Coal burned per square foot of grate per hour	do	25
Cost of fuel to evaporate 1,000 pounds of water		$0.352
Moisture in coal	per cent	30
Refuse in coal	do	$3\frac{1}{2}$

Wm. A. Lamb.

Boiler test of lignite at North Dakota Agricultural College, March 8, 1902.

Duration of test	hours	8.5
Average atmospheric pressure	inches	28.5
Gage pressure	pounds	73.8
Temperature of feed water	°F	144
Kind of fuel		"White ash" lignite.
Moisture in coal	per cent	36
Description of boiler: Common fire tubular boiler, with 62 flues, 3 inches in diameter, 16 feet long; diameter of shell, 60 inches.		
Water-heating surface	square feet	962
Ratio of water-heating surface to grate surface		.025
Coal burned	pounds	3,907
Unburned fuel		None.
Average coal burned in fifteen minutes	pounds	144.91
Total refuse from coal	do	168
Total combustible	do	2,314.5
Average combustible for fifteen minutes	do	68.05
Quality of steam (saturated steam taken as unity)	per cent	0.97
Total water pumped into the boiler	pounds	1,236.5
Water apparently evaporated per pound of fuel burned		3.16
Water actually evaporated, corrected from moisture	pounds	11,994
Equivalent water evaporated into dry steam from and at 212° F	do	13,228
Equivalent evaporation into dry steam from and at 212° F. per pound of dry coal burned	pounds	3.385
Coal burned per square foot of grate surface per hour	do	18.38
Water evaporated from and at 212° F. per square foot of heating surface	pounds	1.606
Equivalent evaporation into dry steam per pound of combustible		5.68
Average ash	per cent	9.03
Combustible	do	90.97
Gas analysis:		
CO_2	do	7
O	do	6
CO	do	1.05

Test conducted by Lewis Larson.

In the foregoing tests natural draft only was used.

Test under forced draft.—On November 17, 1902, a preliminary test of lignite coal from the mine of the Kenmare Coal Company was made under boilers No. 1 and No. 3 of the State University heating plant. During the winter of 1904 more elaborate tests were made under boilers provided with lignite fire-brick arches and under boilers without arches, which it is hoped will settle the disputed question as to the real worth of these arches. For the test given below a steam calorimeter was not available, and the water fed to the boiler is assumed to have been evaporated. The boilers are fire tubular; diameter of shell, 54 inches. Each contains forty-eight 16-foot flues, with inside diameter of 3½ inches, and each contains 841.76 square feet of heating surface. They are provided with the lignite fire-brick arches, and the test was made under forced draft from a fan.

Test of lignite at State University.

Duration of test ......hours..	$12\frac{1}{2}$
Percentage of moisture as shown by four days' drying ......per cent..	10
Percentage of ash ......do....	7.828
Evaporated per pound of fuel from and at 212° F. ......pounds..	4.307
Evaporated per pound combustible (coal minus ash and water) from and at 212° F ......pounds..	5.242

With boiler and grate conditions about like those used in the test at the asylum for the insane, already quoted, three Iowa coals tested at Des Moines gave per pound of coal a water evaporation from and at 212° F. of 5.44, 5.21, and 6.52 pounds, respectively. Four standard Missouri coals gave 6.84, 6.27, 6.23, and 5.86 pounds, respectively, Comparing the results obtained from lignite with these—taking the evaporative powers of lignite at 4.2 pounds, which is conservative—the lignite appears to be worth 75 per cent of the Iowa coal and 70 per cent of the Missouri.

METHODS OF BURNING.

Automatic stokers.—In plants where considerable quantities of lignite are used automatic stokers with forced drafts give most satisfactory results. At the Fargo-Edison electric plant at Fargo stokers which burn the refuse from the Washburn mine, which consists of the cuttings of the mining machines and the fine coal incidental to blasting, are in successful operatio: and demonstrate clearly the ability of lignite to compete with eastern coal in the Red River Valley. The lignite, varying in size from dust to fragments of half a pound weight, is shoveled into hoppers and fed into the furnace by a screw 8 or 9 inches in diameter, the flanges being 6 inches apart. Forced draft is introduced into the ash pit. The cost of firing is greatly reduced and the fires are exceedingly uniform. Other forms of stokers are doubtless practical.

When an economic method of drying the lignite before shipping from the mine is found it will be possible to save 30 per cent of the freight. With automatis stokers, the reduction of the lignite to fragments in the process of drying will be advantageous.

Forced draft and arches.—On account of the gases, volatile at a moderate temperature, that lignite contains, special devices have been introduced in furnaces intended for its consumption, by which these gases shall be promptly raised to the temperature necessary to secure their complete combustion. For this purpose there is often built over the front of the fire box an arch of fire brick, which, becoming intensely hot, secures the combustion of the gases that come in contact with it. That it is useful for this purpose there can be no question. The question remains as to whether it adds to the efficiency of the coal, since it shuts off a portion of the boiler from direct contact with the fire and interferes with firing, when fuel is fed with a shovel. To a certain extent the bricks themselves conduct heat to the boiler. The value of these arches is not fully demonstrated and the cost of their installation is considerable.

Forced draft is convenient if the plant is large, but lignite is giving excellent results in a number of plants where natural draft only is used. With forced draft a short stack is sufficient, and this saving over the construction of a tall chimney is often enough to pay for the installation of the fan. The forced draft is introduced into the center of the ash pit and there caused to spread out, so that it reaches all parts of the grate uniformly. Induced draft is not recommended for any purpose in connection with lignite, though a combination of forced and induced drafts seems to solve satisfactorily certain difficulties in burning brick.

Natural draft.—Very satisfactory results are being obtained with lignite and natural draft at the Minot electric-light plant, the Kenmare roller mill, and similar institutions throughout the State. With natural draft a large boiler and grate surface are desirable, though not absolutely essential, and more experience in firing lignite is necessary. The fires should not be allowed to fall off, for if green lignite is thrown into the furnace when the steam is falling, it acts like a blanket, and temporarily smothers the fire. Fuel should be added when the fire is high and by the time the steam gage begins to drop the fresh lignite has been dried and is ready to burn. It is a good plan to fire but one side of the furnace at a time.

Commercial use.—Two large flouring mills, at Mandan and Jamestown, use lignite exclusively for fuel. The plant of the Russell-Miller Milling Company, at Jamestown, a 500-barrel mill, uses a single boiler, 72 inches by 16 feet, with seventy-two 4-inch flues. Shaking grates, giving an area of 36 square feet with $\frac{1}{2}$-inch air spaces, are used. Forced draft secured by a fan is employed, and 170 horsepower is maintained for twelve hours with the use of 7,600 pounds of Washburn lignite. The engine is a Corliss compound condensing, rated at only 165 horsepower. A careful test has shown that 3.73 pounds of Wilton lignite will maintain 1 horsepower per hour. With lignite at $2.45 at the mill, the cost of fuel per barrel of flour is 4.5 cents.

The Hebron roller mill burns 4 tons of lignite in twenty-four hours, with an output of 100 barrels of flour, besides custom work. Natural draft and ordinary grates are used.

The Kenmare roller mill, using a boiler 66 inches in diameter and 16 feet long, and grate with $\frac{3}{8}$-inch openings, uses 161 pounds of slack lignite per hour to generate 40 horsepower, the steam pressure being 65 pounds.

The Washburn roller mill maintains 30 horsepower for twelve hours with $1\frac{1}{2}$ tons of lignite. The boiler is 12 feet by 36 inches, and the engine small and crowded.

The New Salem Roller Mill Company is operating a 125-barrel mill to its full capacity. The boiler is 14 feet by 52 inches, and the engine is rated at 75 horsepower. Forced draft is employed. In twelve hours 3,700 pounds of lignite are burned.

The electric plant at Dickinson burns lignite under a boiler 72 inches in diameter and 17 feet long, using ordinary grates and forced draft, the fan being driven by a 2-horsepower motor.

The Minot Electric Light Company employs 2 boilers 16 feet long and 54 inches in diameter. Fifty horsepower is maintained for ten hours with 2 tons of green lignite. Natural draft is used, and the engineer does the firing also.

PUMPING WATER WITH LIGNITE.

By CHARLES S. MAGOWAN.

The computations on page 26 indicate the amount of lignite that will be required to raise water to the level of the various flats found on the streams in western North Dakota.

DUTY OF WATER.

The first question that presents itself is that of the duty of water. In the absence of definite data on this point from North Dakota it is necessary to rely on the results of irrigators who have worked under somewhat similar conditions. Wilson [a] records that in Montana a second-foot serves about 80 acres, and that from 15 to 18 inches in depth during an irrigating season is believed to be sufficient. Mr. Wilson makes the general statement that 1,000 gallons per minute will irrigate from 5 to 10 acres per day, and in the course of a season about 100 acres. If water is supplied to a 10-acre tract at the rate of 1,000 gallons per minute for twenty-four hours, the depth of the water over the whole tract will be 5.58 inches. If water to this depth applied five times during the irrigating season is sufficient, a plant of this capactiy should care for 200 acres. This statement is made because it is desired to use 1,000 gallons per minute and multiples thereof in discussing pump efficiencies.

[a] Manual of Irrigation and Engineering, 1903, pp. 55, 56.

CENTRIFUGAL PUMPS.

Centrifugal pumps only are discussed, since it is believed that in view of recent improvements that have been made in their construction no other pump can so economically handle large quantities of water under the given conditions, even for the higher lifts. The discussion is based on belt-driven centrifugal pumps, though some reference will be made to steam centrifugal pumping engines—that is, to machines where engine and pump are directly connected, being built on the same base.

The fuel that will be used in the locality under consideration is lignite that in service tests has been proved to have an evaporative power of 4.2 pounds of water from and at 212° F. per pound of fuel. This value will be used in the computations.

It is contemplated that engines will be used which will deliver at least 1 horsepower for every 35 pounds of steam furnished. This is a low-engine efficiency, and should be realized even under extremely adverse circumstances. By using engines of higher grade—and these should be employed with the larger pumps, where compound, condensing, triple-expansion, or even quadruple-expansion engines might be economically used—the efficiency would be more than doubled, the fuel consumption being correspondingly reduced.

EFFICIENCY OF PUMPS.

The accompanying table shows the capacities and efficiencies of centrifugal pumps of several sizes, all belt driven, together with the amounts of lignite that will probably be required to lift the water to various heights.

The per cent of pump efficiency noted in the table is obtained by comparing the amount of work realized with the amount of power applied to the shaft of the pump, and it is well to note that the efficiency increases as the capacity of the pump increases, thus favoring the installation of large plants.

The prices quoted are those furnished by manufacturers' agents, and are usually f. o. b. at Chicago or an eastern factory. A considerable range in price is noted, the difference being due to differences in weight, construction, and finish.

A new form of centrifugal pump known as the "Volute" is being placed upon the market at the present time, for which claims of increased efficiency are made, the claim being based on the increased care in the manufacture of the wheel and especially in the fitting of the runner, thus lessening the loss from "slip" otherwise sustained.

Capacities, efficiencies, and cost of centrifugal pumps, and amounts of lignite required to lift water to specified heights.

Number of pump (diameter in inches of discharge opening).	Capacity in gallons per minute.	Horsepower delivered to shaft of pump necessary to effect economical discharge at elevations of—				Efficiency of pump (per cent).	Tons[a] of lignite required to furnish power to operate engine and pump 24 hours when lifting the economical discharge to an elevation of—				Price of pumps (approximate) f. o. b.
		20 feet.	40 feet.	60 feet.	80 feet.		20 feet.	40 feet.	60 feet.	80 feet.	
6	1,050	11.8	23.6	35.4	47.2	45	1.2	2.4	3.5	4.7	$120-$280
8	2,000	22.0	44.0	66.0	88.0	46	2.2	4.4	6.6	8.8	190- 390
10	3,000	32.0	64.0	96.0	128.0	47	3.2	6.4	9.6	12.8	240- 570
15	7,000	70.0	140.0	210.0	280.0	51	7.0	14.0	21.0	28.0	400- 840
18	10,000	100.0	200.0	300.0	400.0	52	10.0	20.0	30.0	40.0	700- 900
20	12,000	120.0	240.0	360.0	480.0	53	12.0	24.0	36.0	48.0	900
24	15,000	130.0	260.0	390.0	520.0	58	13.0	26.0	39.0	52.0	[b]1,700
36	32,000	260.0	520.0	780.0	1,040.0	62	26.0	52.0	78.0	104.0	

[a] Price of coal in this region varies from 50 cents to $2 per ton.
[b] Volute.

With the assumptions made above the computations for the fuel consumption become so simple that the tabulation of them seems almost unnecessary. For example, consider a No. 15 pump delivering 7,000 gallons of water per minute against a head of 60 feet. From the table the number of horsepower required is 210, this multiplied by 35, the steam consumption per horsepower per hour, and this by 24, the number of hours considered, and the product divided by 4.2 times 2,000, the result is the number of tons of lignite consumed. In the above case the computation is as follows: $210 \times \frac{35 \times 24}{4.2 \times 2{,}000} = 210 \times \frac{1}{10} = 21.0$. Thus, in any case, the number of tons of lignite that must be supplied to the furnace equals one-tenth of the number of horsepower that is required to operate the pump.

It will be noted that the sizes considered are those that give capacities of about 1,000 gallons per minute or multiples thereof. It is also well to note that the capacity of any of these pumps can be very materially increased by slightly increasing the number of revolutions, but the efficiency will thereby be diminished.

Engines for operating centrifugal pumps must be capable of running at high speed, especially if the pump is operated against a high head. For example, a No. 6 pump operating against an 80-foot head must make 857 revolutions per minute; a No. 24 pump operating against a 20-foot head must make 190 revolutions per minute, and the engine, if directly connected, must work at the same rate. Builders of centrifugal pumps also build engines to meet these requirements and connect them directly to the pumps, especially for the lower lifts.

Wm. A.

A No. 6 centrifugal pump capable of working against a 30-foot head can be bought for $520 or less, while a No. 8 pump that will work against the same head will cost $690. One firm quotes a price of $500 on a 30-horse-power, automatic, high-speed engine, and $1,675 on a 200-horsepower engine. These prices are for engines only. The companies will furnish on request prices on the larger sizes of steam centrifugal pumps.

Some large plants of this kind have been installed and are reported as working successfully. At Albany, N. Y., two 18-inch pumps operated by direct-connected, vertical, cross-compound engines lift 10,000 gallons each per minute, with a reported efficiency of pump and engine of 66.3 per cent, and with a net efficiency of the pump alone of 77 per cent, the lift being 21 feet.

RIVER FLATS AND LIGNITE.

MISSOURI RIVER.

YELLOWSTONE FLATS.

Area and soil.—On entering North Dakota the course of the Yellowstone is toward the northwest, then north, and just before uniting with the Missouri somewhat south of west, its total course in the State amounting to about 15 miles. For this distance it keeps close to the bluffs at the right bank of the valley, leaving broad benches unbroken by meanders on the left. Above the flood plain, which is covered with a dense growth of willows, is a wooded bench from 10 to 15 feet above high water, where large cottonwoods flourish. Its extent may equal 4,000 or 5,000 acres. Ten feet above this and 20 feet above the river at high water is the edge of a beautiful and extensive grassed terrace, which rises gradually for 2 miles to the foot of the bluffs, and which has an area of about 15,000 acres, below a contour line drawn 80 feet above the river. It is not cut up by ravines or gullies and a trench can be carried along the 80-foot contour with but few flumes. With such an initial head, water can be taken to almost any point on the flat.

The soil is a good loam and the upper terrace is already well grassed, though at present it yields hay regularly only where naturally irrigated by water that comes down in Fourmile and Eightmile creeks and other coulees and spreads out over its surface. Much of the woodland lies high enough above the river to be free from ordinary river floods, and is inundated only at rare intervals by the gorging of the ice. In all, at least 15,000 acres on the left bank of the Yellowstone in North Dakota may be regarded as suitable for irrigation if water from the river can be raised 80 feet.

The area in North Dakota is but part of flats that extend into Montana as far as Terry. The fall of the Yellowstone is but 2.7 feet per mile, and a slope of 1 foot per mile would probably be needed in a lateral ditch. A very long lateral would be necessary to take water from the Yellowstone and cover the flats if gravity alone is relied on.

Lignite.—Heavy beds of lignite occur near Sidney, Mont., on the Yellowstone River, 15 miles west of the North Dakota line. On the creeks which empty into the Yellowstone from the south, and notably on Charbonneau Creek, heavy beds of lignite are said to outcrop.

BUFORD-TRENTON FLAT.

Area and soil.—Extending along the north side of the Missouri from the State line to the eastern edge of old Fort Buford Reservation, a distance of 16 miles, is an extensive flat which needs only water to become highly productive. At Trenton station, in the middle of this tract, the river swings in abruptly till it is close to the bluff, narrowing the flat for one-half mile. Enough remains, however, to provide space for a waterway or a pumping plant, so that if water were available and irrigation seemed desirable the level bench both east and west of Trenton could be irrigated from a single station.

The flat includes about 12,000 acres, divided between an upper grassed terrace and a lower wooded bench, the former having about twice the area of the latter. The wooded bench is from 20 to 25 feet above ordinary high water and is said to have been flooded but twice in twenty-eight years, the last time in the spring of 1891. In places it is being cleared and cultivated. Although some portions are sandy, it has for the most part a good soil. The second or grassed terrace rises gradually from the edge of the wooded terrace, where it is about 30 feet above high water, to the bluffs, at the base of which it is 80 feet above the river. It has a strong gumbo soil which grows blue-joint or wheat grass, cactus, and sage when unirrigated, while with irrigation it produces both grass and grain abundantly, yielding 2½ tons of excellent hay to the acre. The Great Northern Railway crosses it, running at the foot of the bluffs, giving ready access to market for produce raised on it.

The efforts now being made by Mr. Edwin Jack and others to irrigate parts of this area are described on pages 50 and 51. It will be possible to irrigate a part of it as they are doing by building reservoirs and diversion dams in the draws that cut the bluffs behind the flat, but for a large part of it the economy of this method may fairly be doubted. For the area as a whole it will be advisable to consider the possibility of raising water from Missouri River.

Lignite.—Only limited quantities of lignite are known in the bluffs just back of this tract, though large beds may sometime be discovered. Two miles from Buford, in sec. 31, T. 153, R. 103, a 4-foot bed of good lignite is mined to some extent by stripping. About 75 tons were taken out in the winter of 1902.

On Eightmile Creek, above Jack's ranch, a 3½-foot seam furnishes some lignite, while fuel from Buford is in part brought from the Yellowstone and in part from the seams in Glass Bluffs, across the river. If a pumping station were established at Trenton, where the river cuts back nearly to the bluffs and divides the tract into two parts, it might be practicable to ship coal from the mines already opened near Williston, a distance of only 25 miles. In this case good lignite, f. o. b. at Trenton, will cost $2.50 per ton. The lift at this point, to cover the entire tract of 12,000 acres, will be about 70 feet, though a large part of it could be watered with a lift considerably less.

MUDDY AND MISSOURI RIVER FLATS AT WILLISTON.

Area and soil.—The Muddy is the main tributary of the Missouri from the east and north in North Dakota. Its drainage area includes nearly one-half of Williams County, or 700 square miles. In addition to a water supply from direct rainfall, it is fed by a number of perennial springs. On June 27, 1903, it had a flow of 18 second-feet, an amount said to be normal for that season of the year. Its valley is broad and, in the main, fertile. The bottom lands are often a mile wide, while a strip half a mile wide fit for irrigation may be counted on for 20 miles or more from its mouth. There may be 10,000 acres along the stream that could be irrigated if water can be found for so large an area. Along its tributaries there is much land not included in the above estimate, portions of which are already irrigated, mainly by diversion dams for spring flooding.

To be taken with the Muddy River flats are 3,000 or 4,000 acres on the Missouri between Williston and the mouth of the Muddy. It is probable that the amount of water that the Muddy annually contributes to the Missouri is more than adequate to water the 15,000 acres that lie near it, but it has not been demonstrated that a large reservoir can be economically located on the stream. Its valley for 15 miles is broad and seems to offer no point where a short wall can retain a considerable amount of water. If a dam were erected above this point, the water from some of the principal tributaries which empty below would be lost. The Fred Rounsaville dam, which was intended for a diversion dam rather than for a reservoir, is described on page 51.

Lignite.—There is an abundance of lignite on the Muddy and its tributaries, and along the Missouri below Williston.

The following banks have been opened up for local use about Williston, and on the creeks to the north:

The Mackersie bank on Sandy Creek, in sec. 6, T. 154, R. 101.

The Holland bank near Muddy River, 6 miles north of Williston, where a heavy bed of lignite is exposed.

The Lovejoy mine on Stony Creek, where a considerable bed outcrops near the Great Northern Railway.

The mine of the Pioneer Coal Company, which is more extensively developed than any of these, and is shipping lignite in considerable quantities. It is located on the railroad, which here follows the valley of Stony Creek, in sec. 26, T. 15, R. 100. The bed mined is 6 feet thick.

The Miller mine, located 4 miles east of Williston on Cedar Coulee, a tributary of the Missouri. A 12-foot bed here outcrops and will furnish a vast amount of excellent coal.

A number of lignite outcrops 4 to 6 feet thick, which occur along Cow Creek, a tributary of the Muddy, and are mined to some extent for local use.

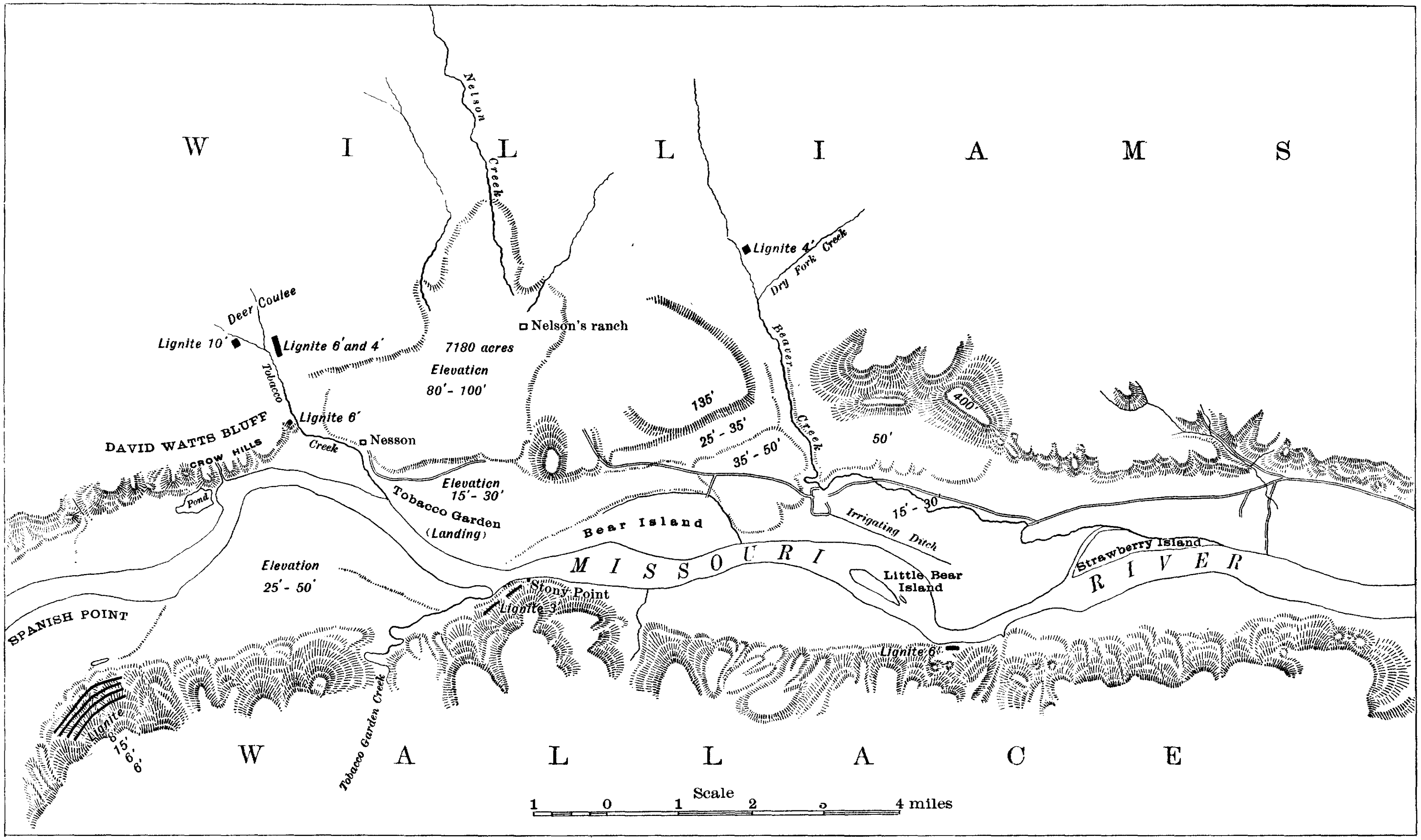
The old Dahl mine, 3 miles southeast of Williston, located on a 4-foot outcrop in the Missouri River bluffs on the left bank of the river.

Eight lignite beds, the heaviest being 4 feet thick, which outcrop in a single vertical section a mile farther down the river on the right bank.

NESSON-HOFFLUND FLATS.

The post-offices of Nesson and Hofflund are situated on Missouri River about 30 miles east of Williston and 14 miles south of the Great Northern Railway, the nearest station being the town of Ray; Hofflund is 6 miles east of Nesson. In this vicinity the Missouri receives a number of tributaries; Tobacco Garden and Clark creeks unite with it from the south, and Tobacco and Beaver creeks and White Earth River from the north.

Area and soil.—Two extensive flats or terraces are developed here, one from 20 to 40 feet above high water, extending about 6 miles along the river from Nesson to Hofflund, and the other from 80 to 100 feet high, located back of Nesson. The upper flat includes 7,500 acres held by more than 30 homesteaders and settlers; the lower includes about 6,000 acres. The soil of the upper, excepting a narrow gravelly strip along the lower edge, is composed of sandy loam with clay subsoil; that of the lower is of 1 to 4 feet of fertile sandy loam, with sand for a subsoil. Only a portion of the lower flat is wooded, the woodland at this point being confined principally to the flood



MAP OF NESSON-HOFFLUND FLATS.

plain, which is not here considered a part of the lower terrace. A portion of this terrace is being carried away by inroads of the river, but the loss due to this cause is not serious enough to interfere with any scheme for the development of the flat as a whole. The slope of the surface of both terraces is favorable to irrigation.

For many reasons the region invites study with reference to the possibility of irrigation. The area, especially when both terraces are taken together, is considerable, the soil is inviting, and the distance from a railroad shipping point in only 14 miles. Heavy seams of lignite of good quality outcrop in the immediate vicinity, and a pumping station that would furnish water for the lower flat (6,000 acres) may, it is thought, be placed close to one of these outcrops, and the expense of hauling fuel may thus be greatly reduced or wholly obviated.

Water supply.—On account of the lift it will hardly be practicable to irrigate the upper flat with water drawn from the river, but Tobacco, Nelson, and Beaver creeks may be considered as possible sources of supply.

Tobacco Creek, which unites with the Missouri at Nesson post-office, has a drainage area of 20 square miles, and is fed by strong springs. Cusack Springs, at the source of its west fork, in sec. 12, T. 154, R. 98, are perennial and flow 3 second-feet even in midsummer. Deer Coulee heads at a spring about as strong as the Cusack and unites with Tobacco Creek a few miles above Nesson. During the summer the creek suffers some loss of volume because of the porous nature of the stream bed at some points. On July 4, 1903, it had a flow of 5 second-feet at its mouth, an amount somewhat less than that of its spring sources.

At least two suitable reservoir sites seem to exist on Tobacco Creek, one occurring a mile back of the upper Nesson flat, where the creek emerges from the bluffs. Another site with apparently a larger capacity occurs 5 miles farther up the creek. However, the ability of the creek to furnish water enough to fill extensive reservoirs has not been demonstrated. Nelson Creek, which drains 40 square miles, could also be used, as it is now used in a measure, in irrigating the upper flat. It is spring fed, though the springs are weak, and most of its available water is due to the melting of snow. In another chapter the tracts at present irrigated in this vicinity will be noted.

Beaver Creek drains 120 square miles in the southeastern part of Williams County. On reaching the Missouri River flats it turns to the east and its bed gradually becomes ill defined, and at last its water is spread over the nearly level surface. Six miles above its mouth, on July 8, the flow was 18 second-feet, which was considerably more than the flow nearer the mouth. In the spring of an ordinary year the discharge is considerable. The descent of the stream is rapid, and it seems possible to utilize the water, if it can be properly stored, to irrigate at least a part of the upper terrace.

The water from these three creeks seems sufficient to irrigate the 7,500 acres on the upper flat, which, on account of their elevation of from 80 to 100 feet, may not profit by any scheme to utilize the water of the Missouri.

On these creeks bowlders are fairly abundant. Aside from these, and beds of soft sandstone, no other stone occurs in the vicinity that could be used in reservoir construction.

Lignite.—For the lower flat, which includes 6,000 acres, pumping from the Missouri may be practical, for fuel is abundant, as shown by the following list of lignite outcrops that occur in this region. At Spanish Point, on the opposite side of the river and 4 miles farther up, four heavy beds outcrop in the bluffs. The aneroid gave the following elevations for the beds:

Relative altitudes of lignite beds near Nesson-Hofflund flats.

	Feet.
Top of bluff	2,850
Lignite, 3 feet, at	2,730
Lignite, 6 feet, good, at	2,690
Lignite, 15 feet, good, at	2,500
Lignite, 8 feet, good, at	2,450
High water of river, about	2,400

The elevations show merely the relative positions of the beds and may vary considerably from the absolute elevations. The bluff is one of the highest in the State.

On Deer Coulee, a tributary of Beaver Creek, at the Marmon ranch, 4 miles from Nesson, a 10-foot seam of good lignite outcrops, from which a strong spring issues. A seam of similar thickness is reported at a number of points at about the same elevation as this outcrop, and the bed may be regarded as rather extensive.

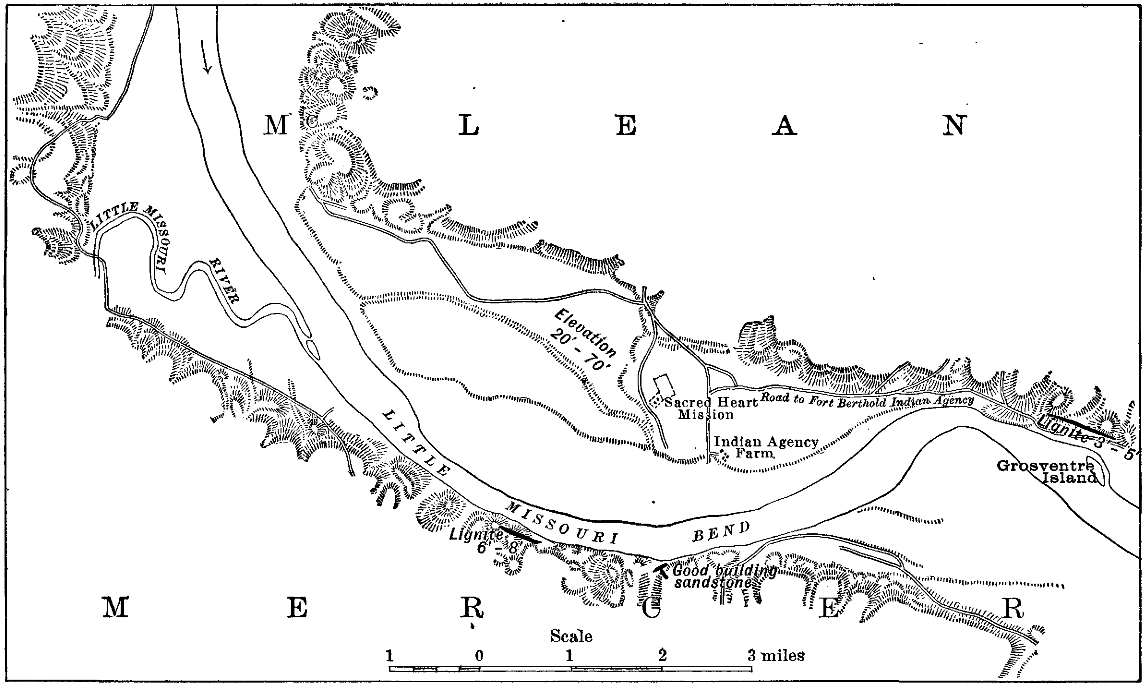
Along Tobacco Creek two seams, 6 and 8 feet thick, outcrop at a number of points, both seams often being exposed in the same vertical section. They can furnish large quantities of good lignite.

On Beaver Creek a 4-foot bed outcrops frequently and is used locally. Three miles above Hofflund a 10-foot bed is mined somewhat more extensively. An entry has been carried in 30 feet; this lies so low that in high water it is partly filled from the creek.

In the bluffs across the Missouri Mr. H. A. Carey takes coal from a 6-foot seam.

Lauchland's bank, located close to the west end of the lower flat, is said to show a good bed of lignite about 8 feet thick.

At Stony Point, on the right bank of the river between Nesson and Hofflund, two beds of good lignite, each 3 feet thick, were seen, and



MAP OF NEW FORT BERTHOLD AGENCY FLATS, ELBOWOODS, N. DAK.

a heavier bed is said to outcrop at this point. Pl. II illustrates the two flats and gives the location of some of the lignite outcrops.

FORT BERTHOLD AGENCY FLATS.

Area and soil.—The flats about the present agency on the Fort Berthold Reservation, which are low enough to justify study with reference to irrigation by pumping from the Missouri, include 5,000 acres. Of this perhaps 1,200 acres, which were formerly woodland and have been recently burned over, are now practically clear, while 800 acres are still covered with large trees. This woodland area is but 20 feet above high water, has a sandy loam soil, and is very rarely covered by water during ice gorges. Twenty feet above this lies a well-grassed flat of 1,200 acres, and still higher, perhaps 80 feet above the river, is a terrace containing about 2,000 acres.

Lignite.—Lignite outcrops frequently in the vicinity. Just across the river, at high-water level, a bed of 3½ feet of lignite was exposed; the whole bed was reported by the superintendent of the agency to be 10 feet thick. It has supplied coal for the agency during the winter when the river has been low and crossing on the ice possible.

In the bluffs 3½ miles below the agency and on the same side of the river a 9-foot bed with 1 foot of clay in the middle outcrops 50 feet above the low river flat. A half mile farther south the following section is exposed:

Section near Fort Berthold Agency, N. Dak.

	Feet.
Lignite, 6 inches of clay in the middle	6
Clay	20
Lignite	2
Clay	5
Lignite	2
Clay	50
Slope to low river flat	20

All of the lignite in this section seems to be good.

Seven miles below Fort Berthold Agency Mr. W. C. Dean reports a 12-foot bed of lignite, from which he hauls coal to the agency.

Lignite in beds of workable thickness outcrops in the bluffs back of Elbowoods at a number of points. The flats with lignite in the vicinity are shown on Pl. III.

OLD FORT BERTHOLD AGENCY FLAT.

This flat, which is about 12 miles below the present agency, contains about 4,000 acres, which are well grassed. Its elevation is from 20 to 80 feet above Missouri River, which bounds it on the south. In the bluffs just east of the flat a 5-foot bed of good lignite is exposed about 50 feet above the river. On the opposite side of the river a 5-foot bed is mined by stripping. A 4-foot and a 3-foot seam outcrop in the bluffs a mile south of this mine.

FORT STEVENSON FLATS.

These beautiful flats, which include about 7,000 acres, lie on the north side of the river, a few miles northeast of Coalharbor (Pl. IV, *A*). Their elevation is from 30 to 70 feet above the Missouri.

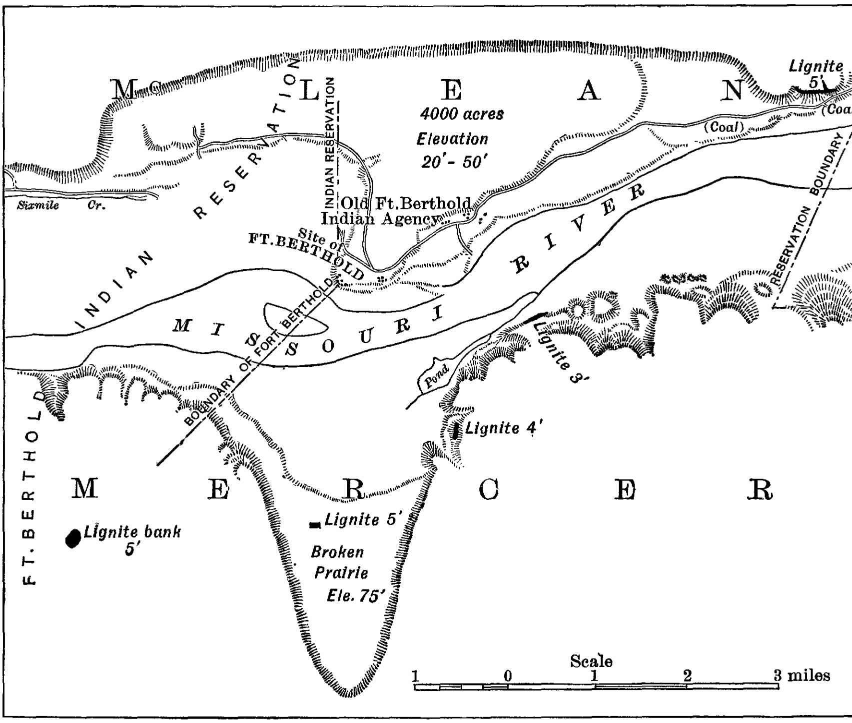
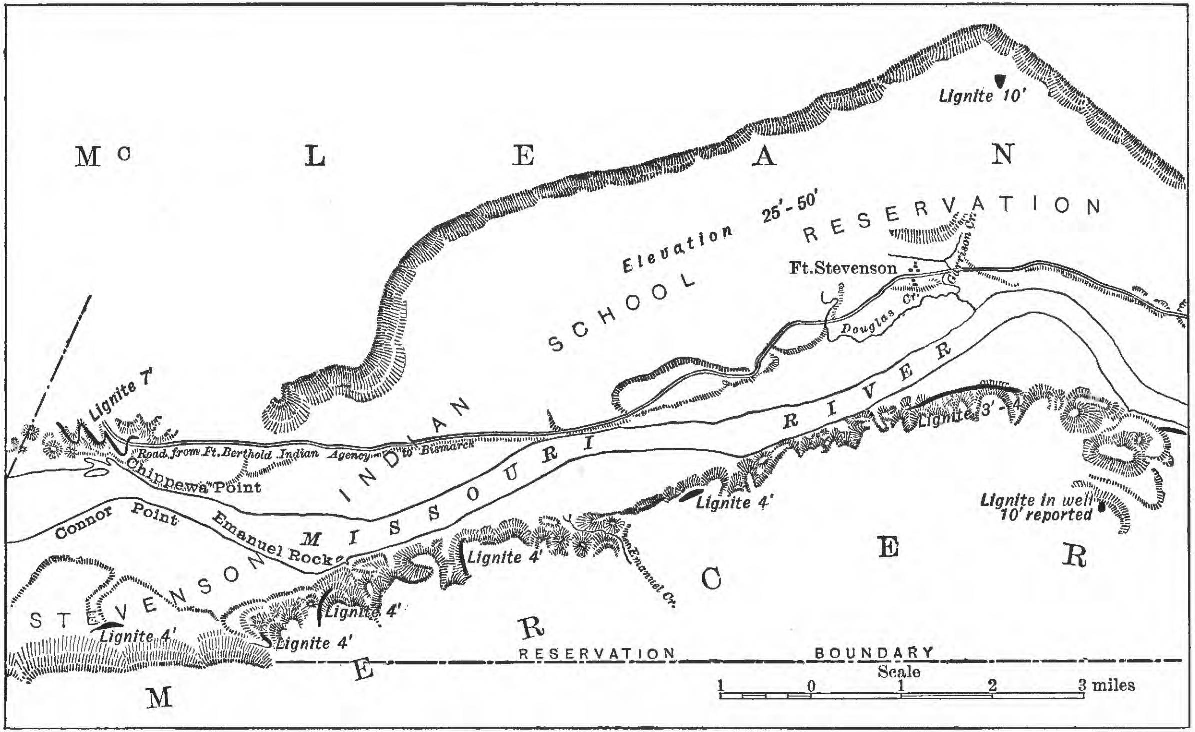


FIG. 2.—Map of flats about old Fort Berthold Agency, N. Dak.

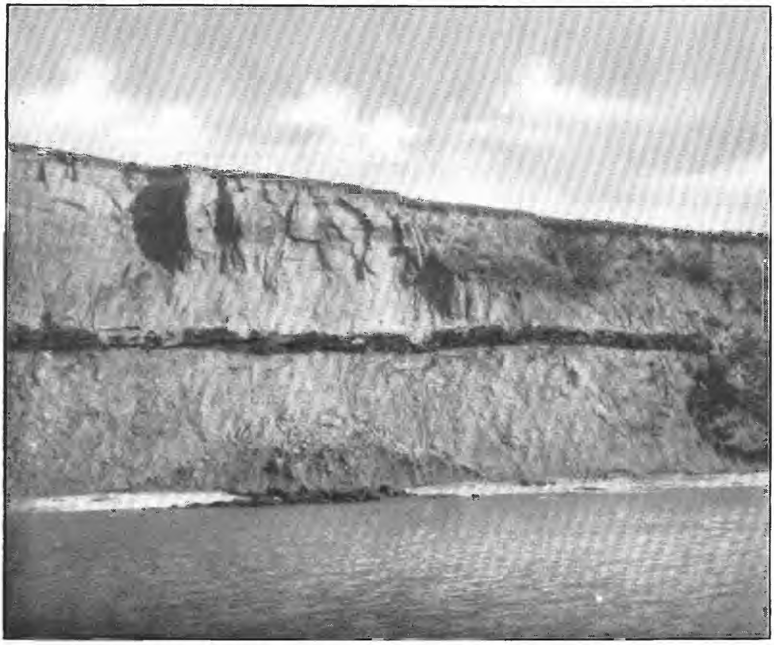
souri. The slope from the bluffs to the river is gradual and uniform. Coal occurs abundantly in the bluffs just back of the flats. For many years lignite was mined here for use at the fort and the Indian school formerly located here. The exact location of the mine was SW. ½ sec. 35, T. 148, R. 85. A seam said to be 14 feet thick was mined by stripping. On the opposite side of the river seams 3 to 4 feet thick are nearly continuous in outcrop for 10 miles.

APPLE RIVER FLATS.

Just south of Bismarck are extensive triangular flats, which lie between Missouri River on the west, Apple River on the east, and the



MAP OF FORT STEVENSON FLATS.



A. A 5-FOOT LIGNITE BED ON THE MISSOURI ABOVE COALHARBOR.

B. SAGEBRUSH FLATS ON THE LITTLE MISSOURI.

river in the bluffs at the point marked B, the following section is exposed:

Section at Big Bend, Missouri River.

	Feet.
Lignite	5.5
Clay	5.0
Lignite	7.0
Clay	50.0
Water level.	

One hundred yards farther down, a section partly covered by talus, gave:

Section at Big Bend, Missouri River.

	Feet.
Lignite	4.5
Clay	5.0
Lignite	3.0
Clay	50.0
Water level.	

The quality of the lignite in all of these beds is good.

Just below Shell Creek, at the point C on the map (Pl. VI), 3½ feet of good lignite outcrops in a cut bank known as "the slide." This same seam probably gives rise to the spring in the bluffs 2 miles to the north, where the Indians have dug through 2 feet of lignite to give freer vent to the water. It is persistent in outcrop for 3 miles to the south, though showing but few good natural exposures. Although the exposures noted indicate a great abundance of lignite in seams from 4 to 7 or more feet thick, the amount of the lift may render pumping from the Missouri out of the question. Shell Creek drains more than 125 square miles, and its water may be available at least for portions of the area and for areas of 600 to 1,000 acres found along its own valley. The flow of water in Shell Creek on July 17, 1903, was about 6 second-feet.

OTHER FLATS.

Some of the many flats on the Missouri, limited in extent, but not so high as to render pumping from the Missouri out of the question, should be noted in addition to the more extensive tracts already described. Much of the woodland on the upper edge of the flood plain can doubtless be cultivated after clearing, since the soil is generally fertile and the value as timber land small. These tracts however are not included in the flats mentioned below.

On the south side of the Missouri, at the edge of the old Fort Berthold Reservation, there is a flat of 1,200 acres lying 40 feet above the river; no coal appears in the immediate vicinity.

On Muddy River cut-off, about 10 miles below Williston, on the north side of the river, are 700 acres, 20 to 40 feet above the river; lignite 6 feet thick shows in the bluffs a mile below.

bluffs back of Bismarck on the north. They have an area of about 5,000 acres, 2,000 acres being only from 20 to 30 feet above the river and partly wooded, while the rest are from 80 to 100 feet above river level. No coal outcrops in the immediate vicinity, but the expense involved in bringing lignite from the thick beds outcropping directly on the river 60 miles above, at Mannhaven and Coalharbor, should not be great. It may be more practical to control the water of Apple River and use it for irrigation purposes, for the stream drains a considerable area and could doubtless furnish all the water needed if it could be properly stored.

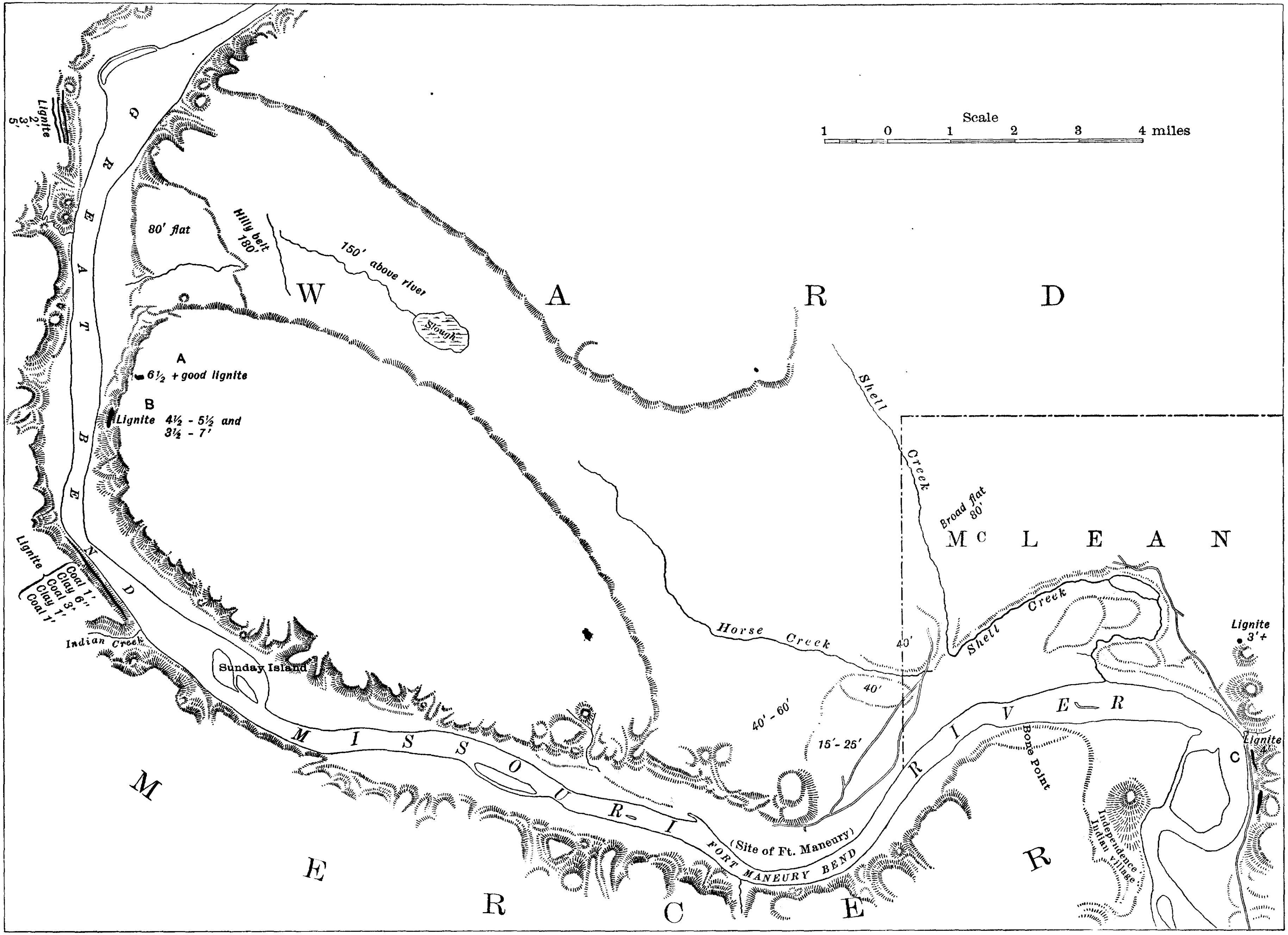
On account of their situation on the outskirts of a city of considerable size and on the Northern Pacific Railway gardening should prove remunerative, and a rather high cost per acre to secure irrigation may be justified.

BIG BEND AND SHELL CREEK FLATS.

Area and soil.—The Missouri River receives the waters of the Little Knife just before entering the Fort Berthold Reservation. Then, instead of pursuing its normal course, it makes a notable bend like a great letter U, which is known as the " Big Bend." Throughout this portion of its course, and in the valley of Shell Creek, which meets it at the lower end of the U, topographic conditions and heavy beds of lignite invite a careful study with reference to irrigation possibilities, though the conclusions that may be reached are probably more uncertain than in the flats already described. The area, however, is large, and as the land lies wholly within the reservation it is still completely under Government control.

The river at the " Big Bend " seems to have been diverted from its course at some time in the past, perhaps by the Wisconsin ice sheet, and compelled to cut a new channel to the west. Its former channel seems to connect the two arms of the U, and to form a valley 2 miles in width, with its center, a third of a mile wide, sloping very gently and unbroken by gullies. Its position with reference to the river and Shell Creek is shown on Pl. VI. At the upper end of the U this old valley is 140 feet above the river; its slope is toward the south, the upper half draining into a large slough in its center, while the lower portion contributes its water to Shell Creek. The area that could be irrigated advantageously, if water could be found, is two-thirds of a mile wide and 15 miles long and includes about 7,000 acres of good soil. In addition to this, on the Missouri at either end of this old valley are flats which contain 3,000 acres.

Lignite.—At the point marked A in Pl. VI, $6\frac{1}{2}$ feet of good lignite outcrops in the bottom of a draw about 80 feet above the river without revealing the bottom of the seam. One-half mile down the



MAP OF THE OLD VALLEY AT THE BIG BEND.

At Barkers Bend is a good flat of 600 acres; 12 feet of lignite appears in "sliding bluff" just below.

Opposite Nesson there are flats containing 1,200 to 1,500 acres from 25 to 50 feet above the river; the heavy beds of lignite in Spanish Point, already described, are only 3 miles away.

Opposite the mouth of White Earth River is an area of 600 acres; there are three lignite beds, the thickest 4 feet deep, in the bluffs just behind.

Opposite the mouth of the Little Knife are 2,000 acres in two terraces, one 20 the other 40 to 80 feet above the river; one lignite bed 4 feet thick was found in the bluffs behind this flat.

At the Indian village of Independence are 1,000 acres 80 feet above the river; lignite outcrops in a 4-foot bed just across the river.

Five miles below the mouth of the Little Missouri, on the east side, is an area of 500 acres in two terraces; lignite outcrops in a $4\frac{1}{2}$-foot bed just opposite.

Just below the Fort Berthold Agency, on the opposite side of the river, is a long narrow flat containing 2,000 acres, 15 to 25 feet above the river, extending to Little Beaver Creek; 4 feet of lignite outcrop in the river bluffs at the latter place.

Just above the town of Mannhaven are 1,500 acres 40 to 50 feet above the river; 8 feet of good lignite outcrop on the river at Mannhaven, with thinner beds, as shown in the following section:

Section near Mannhaven, N. Dak.

	Feet.
Lignite, good	6
Clay	2
Lignite	1
Clay	1
Lignite, good	2
Clay	10
Lignite, good	8
Sand	12
Water level.	

This section may be seen for 2,000 feet along the river.

At Hancock are 1,500 acres in a series of terraces 15 to 25 feet above the river; 4 feet of coal outcrops in the bluffs behind, while across the river the heavy beds, once developed and known as the "Plenty" mine, outcrop. The beds there exposed show the following section:

Section near Hancock, N. Dak.

	Ft.	in.
Lignite	3	
Clay	0	6
Lignite	3	
Clay	2	
Lignite	3	

Mr. F. G. Mattoon is putting in a pumping plant to irrigate portions of these flats.

Two miles above Stanton, on the opposite side of the river, are 1,000 acres, 15 to 25 feet above water level; a 7-foot lignite bed outcrops near the water on the edge of the flat.

Opposite Washburn are 3,000 acres in three terraces, portions of which are subject to irrigation; 6 lignite exposures, showing from 3 to 7 feet of coal, occur in the bluffs and coulees behind the flats.

At Painted Woods Lake are flats containing 3,000 acres; there are 4 feet of lignite in a neighboring draw and a 5-foot bed exposed on a creek on the opposite side of the river near Sanger court-house.

At the mouth of Square Butte Creek, 8 miles above Mandan, flats occur; 2 feet of lignite are reported 2 miles to the north.

Near Mandan and at a number of points farther down the river are extensive flats; no heavy beds of lignite are known to occur near them.

LITTLE MISSOURI RIVER FLATS AND LIGNITE.

Terraces are well developed along the Little Missouri at nearly every point in its course. In a given locality their number may be five or six, and few localities have less than three. Their elevation varies from 20 to 200 feet above the river. No single tract is large, on account of the meandering of the river, but the total area at an elevation moderate enough to make pumping from the river practicable is considerable. A rather careful estimate of the area not more than 30 feet above the river places it at more than 30,000 acres, cut up into tracts ranging in size from 50 to 1,000 acres.

FLATS AND LIGNITE IN THE VICINITY OF YULE.

During the summer of 1902, 9 townships on the upper course of the Little Missouri, with Yule post-office as a center, were studied. There is much diversification in the topography of the country, which includes Little Missouri Valley and its terraces, the "breaks" in the vicinity of the river, and the rolling country back from the river, which furnishes an unequaled summer range for cattle.

Lignite.—Lignite outcrops almost continuously, even in the shallowest of coulees, as well as along the creeks and on the main stream itself. These outcrops are from 6 inches to 40 feet in thickness. Ranchmen seldom find it necessary to go far for fuel. Many of them consider it easier, however, to go to the river in winter and break up the great blocks of coal that the stream has washed out. There are a number of small flats on this stream south of Medora which lie well for irrigation by pumping. More than half of the area had not been surveyed in September, 1902, and it is impossible to cite locations definitely in many cases.

TOWNSHIPS 133 AND 138, RANGE 105.

In townships 133 and 138, range 105, which includes an area from 20 to 40 miles south of the Northern Pacific Railway, are the heads of a number of coulees, which flow eastward into Little Missouri River. In going from north to south, Williams, Garner, Bull Run, Horse, Coal Canyon, Cannonball, Boise, and Bacon creeks are crossed, in about the order named. All of these creeks show lignite more or less continuously from the time that they cut through the sod till they empty into the Little Missouri; their courses vary in length from 10 to 20 miles. None of them, except Cannonball, are shown on an ordinary map.

On Williams Creek, 6 miles from its mouth, the following section is given:

Section on Williams Creek, North Dakota.

	Feet.
Lignite, good	2
Clay	20
Lignite, good	4
Clay	4
Lignite, 1 foot exposed; bottom of bed not found.	

These beds were traced for a mile along the creek. Along the lower course of the stream lignite is said to be abundant.

On Garner Creek exposures of lignite are not abundant, though springs that probably come from the lignite are common, the lignite being concealed by the grassed slopes. A tributary which unites with the creek 8 miles above the Little Missouri is said to show a 4-foot bed.

On Horse Creek for more than 6 miles lignite beds varying in thickness from 3 to 6 feet are exposed at various elevations.

On Coal Canyon Creek an abundance of lignite is exposed along the deep ravine through which the stream flows. A typical section is as follows:

Section on Coal Canyon Creek, North Dakota.

	Feet.
Lignite, fair	5
Clay	1
Lignite, good	7
Clay	1
Lignite, good	1
Creek bottom.	

This exposure occurs 2 miles west of the Little Missouri.

On Cannonball Creek, which empties into the Little Missouri about 25 miles south of Medora and is a stream of some importance, its valley being nearly a mile wide a mile from its mouth, there are 6 feet of good lignite outcrop in a single bed. Along the Little Missouri and its tributary ravines in this vicinity 4 or 5 beds of lignite may be seen, ranging up to 4 feet in thickness.

On Boise Creek, some miles above its mouth, 2 or 3 beds were seen, ranging from 2 to 4 feet in thickness.

On Bacon Creek, at the J. C. Gamel ranch, in sec. 20, T. 133, R. 104, a bed 24 feet thick outcrops. Its quality is good.

On Sand Creek a lignite bed 40 feet thick outcrops near the A. E. Russel ranch, in sec. 31, T. 135, R. 101. The exposure is continuous along the creek for a quarter of a mile, and much of the coal can be obtained by stripping less than 10 feet of earth from the surface. At the north end of the exposure the section given was:

Section on Sand Creek, North Dakota.

	Feet.
Sandstone	2
Clay	10
Lignite	2
Clay	2
Lignite	15
Clay	3
Water level.	

At the south end of the exposure the lignite reached the remarkable thickness shown below:

Section on Sand Creek, North Dakota.

	Feet.
Clay	5
Lignite	3
Clay	2
Lignite	40

The lignite throughout the bed appeared to be of good quality, except that the upper 2 feet were soft. The analysis indicates good quality.

On the Little Missouri near the 777 ranch, a few miles south of Yule, some fine beds outcrop. Rising directly from the water's edge at one point, the beds of clay and lignite reach a height of 110 feet, as shown in fig. 3. The heaviest lignite bed in the section is the lowest, which is more than 12 feet thick.

At Yule and at points between it and Medora 2 or 3 beds of fair thickness and quality occur.

Area.—Well-developed river flats occur along the Little Missouri in this vicinity, at times exceeding 500 acres in extent.

FLATS AND LIGNITE AT AND BELOW MEDORA, N. DAK.

In the Little Missouri Bluffs at Medora, on the Northern Pacific Railway, the section shown in fig. 4 may be seen. The lignite in all the beds is of good quality. It outcrops repeatedly on the west side of the river. Both north and south of Medora for a number of miles lignite is as abundant as at the points cited. At some points, as near the Eaton ranch, it is mined for local use.

The larger flats along this portion of the Little Missouri are noted below, with the amount of lignite known to occur in their vicinity. The land has not yet been surveyed, and locations are noted by referring to ranches in the vicinity.

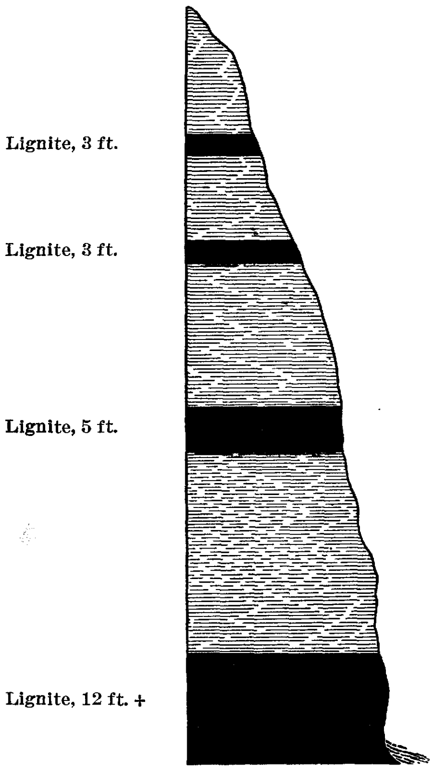


FIG. 3.—Section 30 miles south of Medora, at the 777 ranch, showing lignite seams.

Near the Burgess ranch, 4 miles north of Medora, are several flats from 50 to 160 acres in extent; lignite appears in three beds, each from 3 to 4 feet thick.

Between Burgess and Parkin's ranch, five miles north of Medora, are flats amounting to 400 acres, 100 acres of which are about 25 feet above the river; two lignite beds 4 to 8 feet thick appear.

Near Young's ranch are flats containing 400 acres; lignite occurs in large quantities on Government Creek.

From Young's to Johnson's ranch are flats containing 300 acres.

Near Mikkelson are flats containing 250 acres, 25 feet above the river, and 100 acres in addition in the vicinity; lignite is present in four beds, each from 3 to 5 feet thick; 2 miles below Mikkelson a 18-foot bed is exposed in a small butte. (Pl. VII, *B*.)

Near Carter's ranch, 3 miles below Mikkelson, are flats containing 250 acres and on the opposite side of the river 160 acres; lignite is abundant in the vicinity, a 9-foot bed outcropping 2 miles below the last-named flat.

Between Medora and the mouth of the Little Missouri several small flats ranging from 50 to 500 acres occur, which are from 15 to 30 feet above the water; lignite is abundant all along this portion of the river and is of good quality.

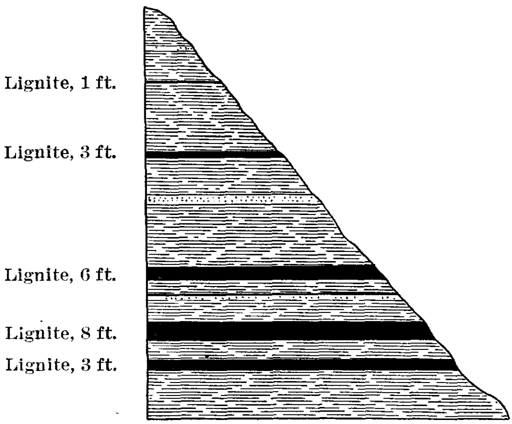


FIG. 4.—Section showing lignite seams in the bluffs at Medora.

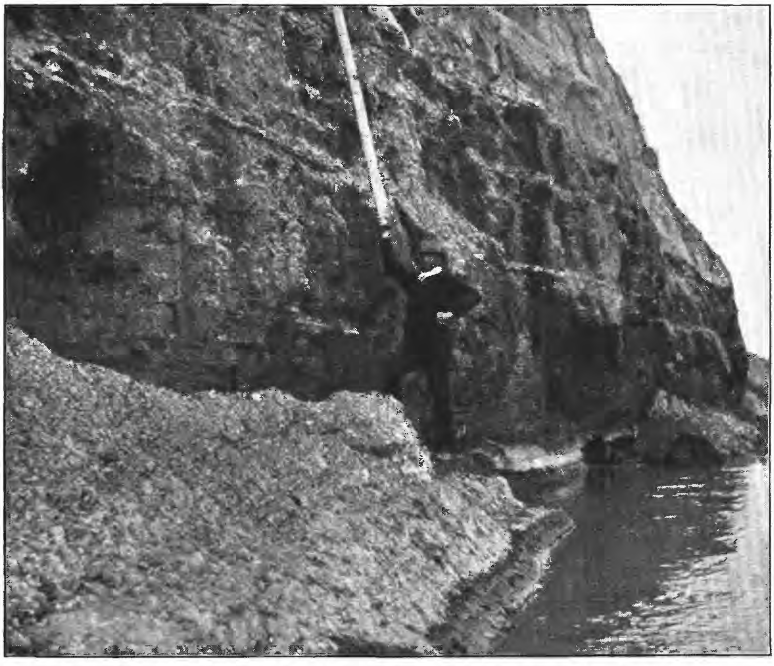
Near President Roosevelt's old ranch are flats which have an area of 200 acres; there is a 5-foot lignite bed in the adjacent draw.

Near Clark and Morgan ranches large flats occur at the mouths of Blacktail and Whitetail creeks, which here unite with the Little Missouri from the east; they include 400 to 600 acres, with a 10-foot lignite bed outcropping just across the river and 3- to 4-foot beds showing on the same side.

Near the mouth of Beaver Creek, both on this creek and on the Little Missouri, are large flats, the total area practicable for irrigation being more than 600 acres. (Pl. VIII, *A*.) Lignite in beds 3 to 4 feet thick may be seen at a number of points in adjacent bluffs.

Near Simpson's ranch and Magpie Creek is an area of 500 acres, from 15 to 25 feet above the river, broken into three tracts; two beds of lignite are exposed near by, each 3 feet thick.

A. AN 8-FOOT LIGNITE BED 8 MILES NORTH OF MEDORA.



B. AN 18-FOOT LIGNITE BED 2 MILES BELOW MIKKELSON.

Near Gore brothers' ranch are level flats containing 200 acres 15 to 25 feet above the river; lignite appears in two 3-foot beds.

Near Martin's ranch and Bolan and Redwing creeks is a 200-acre flat; there are lignite beds from 2 to 10 feet thick.

CHERRY AND TOBACCO GARDEN CREEK FLATS.

Area and water supply.—From the first permanent eastward bend of the Little Missouri northeast to the Missouri there extends an ancient river valley, drained by Cherry Creek into the former stream and by Tobacco Garden Creek into the latter, and also by the greater parts of Redwing and Bolan creeks.

This valley is indicated by broken lines on Pl. I; it seems to mark the course of the Little Missouri during some pre-Glacial period. It is about 30 miles long, and from 1 to 5 miles wide.

The highest point of the old valley is Bear Butte, which forms the divide between Redwing and Cherry creeks. Numerous tributaries, which carry considerable water in the spring, but are dry in the summer, enter both Cherry and Redwing creeks as they flow through the old valley. Most of these tributaries head in the divide between the Yellowstone and Little Missouri, and attain a maximum length of 4 or 5 miles. They are significant in connection with the irrigation of the valley, for land here is being taken under the desert land act, the intention being to irrigate by building reservoirs in the small tributaries to the creeks just named.

The bluffs back of the old valley are very abrupt. Under present conditions the most fertile portion of the valley is found on the upper part of Cherry Creek. The X ranch, owned by the Converse Cattle Company, grazed nearly 5,000 cattle on this portion of the valley during the entire summer of 1902. Irrigation by means of reservoirs in the tributary creeks and coulees is practicable to some extent.

FLATS AT AND BELOW FORT BERTHOLD.

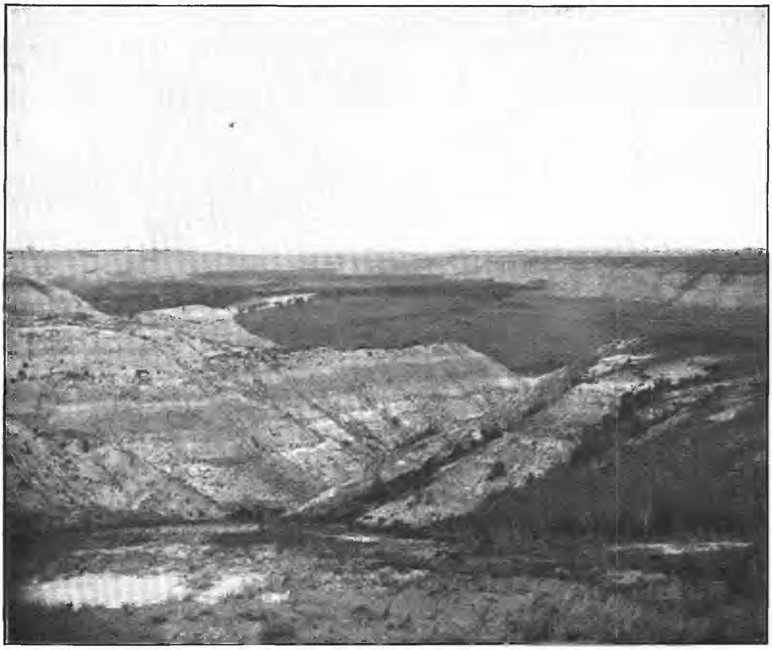
After entering the Fort Berthold Reservation the flats on the Little Missouri become insignificant.

LIGNITE OUTCROPS.

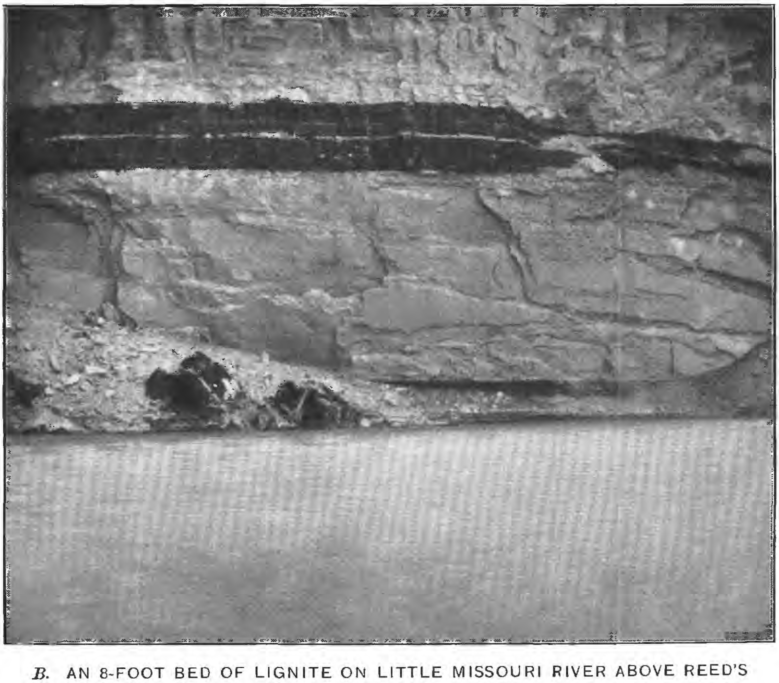
A list of the more important lignite outcrops on the Little Missouri, and their position with reference to the river and flats, is given in the following table:

The more important lignite outcrops on Little Missouri River, North Dakota.

Location.	Number of beds.	Thickness in feet.	Extent of outcrop.	Elevation above river.	Distance from river.	Distance from flats.
4 miles from Medora, in buttes.	1	10	20 feet	225 feet	2½ miles	2½ miles.
Opposite Burgess's ranch	1	3	20 rods	River level	On river	40 rods.
	1	8				
2 miles below Burgess	1	5	4 rods	do	do	A few rods.
	1	6				
5 miles blow Burgess	1	3	Several rods	do	do	1 mile.
	1	5				
3 miles west of Parker's ranch.	1	3	do	8 and 15 feet	do	
	1	3				
3 miles east of Young's ranch.	1	3		200 and 300 feet.	3 miles	3 miles.
	1	10				
2 miles south of Mikkelson	4	17 to 18	10 rods	Near water	On river	1 rod.
2 miles north of Mikkelson	1	16	6 rods	Water line	do	½ mile.
Reed's ranch	1	8	Several rods	40 feet	do	Just across the river.
	1	10				
Mouth of Beaver Creek	1	3	1 mile	20 to 40 feet	do	Across river.
	1	8				
Near Morgan's ranch	1	3	do	River level	do	Edge of flats.
	1	7	½ mile	30 to 60 feet	do	40 rods.
	1	10	1 mile	30 feet	10 rods	80 rods.
Near Simpson's ranch	2	6 to 8	½ mile	0 to 60 feet	On river	Across river.
Bolan Creek	1	10 to 12		100 feet	1½ miles	2 miles.
	4	3 to 4				
Redwing Creek	1	10 to 12		do	1 mile	½ mile.
	1	4			On river	¼ mile.
Boehm's ranch	1	3 to 4	10 rods			Across river.
Squaw Creek	1	4 to 5	14 rods	300 feet	1 mile	½ mile.
	1	4 to 5	4 rods	200 feet	do	1 mile.
Near southwest corner Indian reservation.	1	12	2 to 3 miles			A few rods.
Near Manning's ranch	1	12	20 rods	10 to 20 feet	On river	40 rods.
	1	5 to 6	do		do	Do.



A. FLATS ON LITTLE MISSOURI RIVER NEAR BEAVER CREEK.



B. AN 8-FOOT BED OF LIGNITE ON LITTLE MISSOURI RIVER ABOVE REED'S RANCH.

FLATS AND LIGNITE ON KNIFE RIVER AND TRIBUTARIES.

FLATS.

Knife River.—The Knife River flats are like those along the Little Missouri just described, differing mainly in not being so shut in by high bluffs and in having the slopes to the uplands comparatively gradual.

The flow of water in Knife River even in summer is often considerable. On July 31, 1903, it was too deep to ford near its mouth, and when seen again at the same point on August 21 there was a foot of swiftly flowing water over the fords, which were 25 feet or more wide.

For 15 miles from its mouth the flats are extensive, often reaching a width of a mile and including in all about 4,000 acres, which lie from 15 to 25 feet above the river. Lignite is found along all the bluffs at the mouth and outcrops in nearly every coulee. An 8-foot bed is mined 4 miles south of the river on the west bank of Brody Creek.

Below Hazen the river flats within 4 miles embrace 2,500 acres. A 4-foot lignite bed is found 4 miles north of Hazen. From Hazen to the mouth of Spring Creek, the main tribuary of Knife River, a distance of 10 miles, are flats that lie 20 feet above the river and have an area of 2,000 to 3,000 acres.

From Broncho to Rock Springs, on Knife River, the average width of the flats is one-half mile, and the total acreage considerable. Four feet of lignite outcrop in sec. 14, T. 143, R. 94.

Spring Creek.—Flats extend up Spring Creek for a mile, above which to Halliday they are cut up into small tracts of 30 to 40 acres. Lignite in two beds outcrops near O'Neil's ranch.

From Halliday to Pelton's ranch, on Spring Creek, a distance of about 12 miles, flats are extensive and include about 4,000 acres. Spring Creek is perennial, and its flow is considerable. At Paulson's ranch a 16-foot bed of good lignite outcrops. It is covered by only 10 to 20 feet of clay, and furnishes fuel for the neighboring ranches. There is much coal in the vicinity of Halliday, as shown by springs and outcrops along the creek. At Olafson's ranch two beds of good lignite 2 and 3 feet thick outcrop on the north side of the creek. Six miles north of Halliday on Hans Creek a spring, which issues from a lignite outcrop, is used for irrigation. On the south side of this creek a bed said to be 10 feet thick is mined in winter.

Farmers Valley.—Farmers Valley, which extends from Hebron to a point north of Gladstone, and then north through Deep Creek Valley to Rock Spring post-office, contains 10,000 acres of land fit for irrigation if water could be found. In sec. 33, T. 141, R. 93, a possible reservoir site exists.

LIGNITE OUTCROPS.

The following table gives the more important lignite outcrops on Knife River and Spring Creek and their position with reference to river flats:

Lignite outcrops on Knife River.

Location.	Number of beds.	Thickness in feet.	Extent of outcrop.	Elevation above stream.	Distance from stream.	Distance from flats.
Sec. 9, T. 144, R. 89, G. Weige	1	5 to 6	10 feet		On creek.	On edge of flat.
2½ miles east of Weige	1	10	20 rods	Taken on report; said to be on edge of flat and accessible.		
5 miles west of Weige	1	5	10 rods			Edge of flat.
Olafson's at Halliday	2	2 to 3	do		On creek.	Edge of 200-acre flat.
Opposite Halliday	1	5	5 rods		do	Faces flat.
Sec. 15, T. 145, R. 92	1	4	4 rods		1 mile	
Anderson's, sec. 28, T. 146, R. 92.	1	a10			7 miles	
Paulson's, sec. 27, T. 145, R. 93.	1	16	40 rods		On creek.	Near 400-acre flat.
Paulson's, sec. 12, T. 142, R. 93.	1	5 to 6	5 rods	30 feet		Near 600-acre flat.
Corey's, sec. 28, T. 144, R. 96	1	4	Extensive			
Beck's, sec. 4, T. 144, R. 97.	1	b4		This bed is on Little Knife, between Fayette and Rickardton.		
Fayette	1	2 to 3	20 rods	Beds run along creek at elevation of 10 feet; 6-foot bed reported 6 miles west.		
	1	4				
Brannen's, sec. 34, T. 144, R. 99.	1	5		Placed upon the Little Missouri divide.		
5 miles south of Brannen's.	1	5		Extends along draw for several miles.		
Sec. 13, T. 141, R. 93, north of Richardton.	1	4				Near 600-acre flat.
2½ miles northwest of Richardton.	1	4				
Sec. 33, T. 141, R. 93	1	4				
Sec. 14, T. 143, R. 94	1	4	40 rods	20 feet	On creek.	Do.
Sec. 13, T. 143, R. 94; O. Ziner's.	1	3 to 4				2½ miles.
Sec. 15, T. 143, R. 94; Bailey.	1	4	5 rods		Near Knife River.	Near 1,000-acre flat.
Secs. 9 and 2, T. 142, R. 92; M. Hanson.	1	5 to 6				Near 600-acre flat.
Secs. 5, 7, and 9, T. 140, R. 90; Crowleys.	1	3 to 4				
	1	3 to 4				
	1	6 to 8				
Sec. 4, T. 142, R. 90; F. M. Smith.	1	4 to 5				Near 200-acre flat.
Sec. 14, T. 143, R. 89; Gerechts.	1	5 to 6				

a Reported. b At spring.

On the lower Knife River lignite is obtained at many points on the north side of the stream. The bed is 3 to 4 feet thick. Lignite may also be obtained from a bank 4 miles south of Hazen, where the bed is 8 to 10 feet thick.

FLATS AND LIGNITE ON HEART RIVER AND TRIBUTARIES.

FLATS.

Attractive flats, each containing a few hundred acres, may be found along Heart River and its tributary, Green River.

LIGNITE.

Heart River.—Lignite outcrops are frequent along both the Heart and the Green, some of the largest mines in the State being located in their vicinity. The New Salem mines, only 12 miles north of Heart River, had an output of 17,000 tons during the year 1902–3. Other mines at Sims, no farther from the river, are producing extensively. Between New Salem and the river 5-foot beds outcrop at a number of points and are mined on the strip-pit plan.

The mine of the Consolidated Coal Company at Lehigh, 3 miles east of Dickinson, has developed a remarkably fine bed of lignite

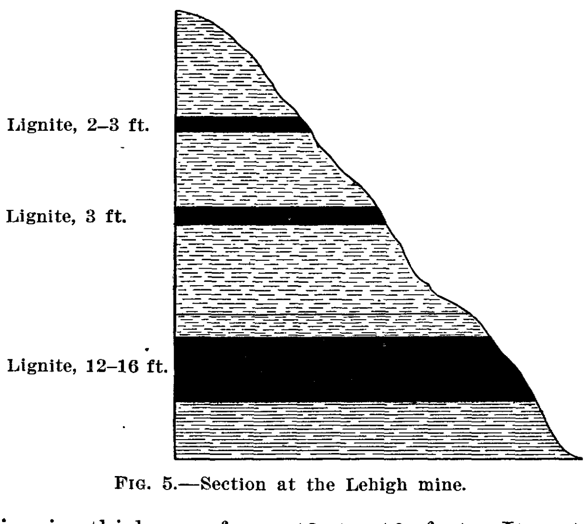


FIG. 5.—Section at the Lehigh mine.

which varies in thickness from 12 to 16 feet. It outcrops continuously along the river for 3 miles. Thirty feet above this thick bed a 3-foot bed is frequently exposed, and above this another and more variable bed. (Fig. 5.)

At two points on the outskirts of Dickinson lignite is mined in considerable quantities. At the plant of the Dickinson Pressed Brick and Fire Clay Company a 5-foot bed is mined by stripping. The Lenneville mine, half a mile east of Dickinson, shows a bed varying in thickness from 4 to 8 feet. Lignite from this mine ordinarily sells for $1.50 per ton at the mine.

Three and 4 miles west of Dickinson, on Heart River, a 4-foot and a 7-foot bed outcrop frequently. The lignite at the Bird-Stone mine, in sec. 6, T. 139, R. 98, outcrops on Heart River, and may be seen from the Northern Pacific Railway. The bed is 16 feet thick, the upper part being inferior in quality at the outcrop; the lower 8 feet is excellent. In section 8 of the same township the bed outcrops again. On the south side of the Little Heart, between South Heart and Belfield, a 6-foot bed of excellent coal occurs. It may be seen best in sec. 16, T. 139, R. 98, a school section.

Green River.—North of Dickinson lignite abounds on Green River throughout its course. Near its mouth at Gladstone beds of excellent quality, though not exceeding 5 feet in thickness, are found on the Rust and A. B. Powers farms in secs. 26 and 27, T. 140, R. 95. The exposures are directly on the river and near water level. Two miles farther up the stream, in W. ½ sec. 22, T. 140, R. 95, a 3-foot bed of good lignite is mined by the owner of the ranch on which it occurs. At the Kupper ranch, due north of Dickinson, a 15-foot bed of excellent lignite outcrops for a long distance on the edge of Green River. This bed is known to be very extensive.

Coalmine Creek.—Coalmine Creek, a tributary of Heart River, which unites with it a mile east of Belfield, shows great quantities of lignite along its course for at least 5 miles. Two good banks were examined, one 6 feet thick in sec. 28, T. 140, R. 98, the other 7 feet thick in sec. 27, T. 140, R. 98. A number of additional openings have been made along this creek from which lignite is taken. In sec. 30, T. 140, R. 99, 5 feet of a bed said to be 9 feet thick may be seen.

Norwegian Creek.—Three miles south of Belfield, on Norwegian Creek, a tributary of the Little Heart, which flows east and unites with the Little Heart 8 miles southeast of Belfield, a number of beds are exposed and slightly opened. They include the Engelhardson bank, in sec. 20, T. 139, R. 99, with lignite 6 feet thick, and the Anderson bank in section 19 of the same township, with a bed 12 feet thick. In the vicinity of all of these lignite outcrops there are flats of moderate elevation.

FLATS AND LIGNITE ON CANNONBALL AND CEDAR RIVERS.

Terraces of different elevations, with a considerable total area, occur along the course of the Cannonball below its union with the Cedar and along both streams for 60 miles above their junction. On account of the meandering of the rivers, and the rather limited width of the terraces, more than 600 acres are rarely found in a single tract. With the data now at hand it does not seem practicable to irrigate areas larger than this by pumping from a single fixed station. It may be, however, that detailed study will show that two or more of these tracts may be connected by ditches and treated as one.

CANNONBALL RIVER FLATS.

Area and soil.—The elevation of the Cannonball flats varies from 10 to 80 feet. The soil is generally fertile, and at many points is well grassed. In places it appears to be gumbo, while at others it is too sandy for agriculture. Taken together these flats have a considerable area, perhaps 30,000 or more acres, with soil and topography favorable for irrigation. As on the Missouri, there are opportunities to form reservoirs on the tributary streams and divert the water so controlled to the flats of the larger stream. The difficulties here, as there, will be found in constructing at reasonable expense reservoirs sufficiently strong to bear the water put upon them by violent storms.

Lignite.—Lignite is not abundant on the Cannonball below Wade post-office, where the Cedar unites with it. Only the following outcrops were noted:

Three feet of coal, reported in Castle or Palace Butte, about 6 miles north of Cannonball post-office, at the mouth of the river. Samples examined were of fair quality.

A 14-inch bed, mined by stripping, about 18 miles from the mouth of the Cannonball, in sec. 21, T. 134, R. 81. The outcrop occurs close to the river.

A bed 2½ feet thick, reported in a bank 4 miles northwest of Shields post-office, and an equal distance from the river.

A bed 18 inches thick, reported 3 miles north of Howe post-office.

A careful search made along the bluffs where good exposures occur brought to light only beds a few inches thick, till the upper Cannonball was reached.

Forty miles east of New England post-office heavy lignite beds outcrop, and appear continuously from this point for 50 miles up the stream. The following may be briefly tabulated:

Lignite beds on upper Cannonball River, North Dakota.

	Feet.
O. S. Chase bank, sec. 31, T. 134, R. 92	2–3, good.
E. C. Barry, bank, sec. 4, T. 133, R. 92	3, good.
Sec. 21, T. 134, R. 94	3, good.
NW. ¼ sec. 22, T. 134, R. 94	3, good.
Secs. 21 and 22, T. 135, R. 96	4, good.
Jacob Reiss bank, sec. 22, T. 136, R. 97	7, good.
John Ermintrout bank, 6 miles northeast of New England	3
Two beds, 5 miles west of New England	9, good.

COALBANK CREEK.

Lignite.—Coalbank Creek, a tributary of the Cannonball, which unites with it near New England, shows good lignite beds frequently; one 4-foot bed may be found 4 miles from the mouth of the creek.

CEDAR RIVER.

Lignite.—On the upper Cedar River lignite is said to be abundant, and judging from observations on the adjacent tributaries of the Cannonball the reports are probably correct. The same statement can be made for the upper Grand River in South Dakota.

PRESENT STATUS OF IRRIGATION IN NORTH DAKOTA.

A great part of the irrigation in North Dakota is due to the stimulus given by the desert-land act. The application of this law in the State seems to have been free from abuse, and a further application of it has been prevented by the fact that extensive areas in the semi-arid portion of the State are not recognized as desert land by the land offices. The only part of the State where desert-land claims may be filed is the northwestern, and here there is always some uncertainty as to what the ruling of the land office will be till each claim is finally inspected.

FLATS PARTLY IRRIGATED.

YELLOWSTONE FLATS.

On the Yellowstone flat in North Dakota, and just over the line in Montana, the following claims have been filed:

Andrew F. Nohle: Reservoir on Fourmile Creek, a tributary of the Yellowstone in Montana, near the boundary line. Fourmile Creek is said to have a drainage area of 24 square miles. The Nohle dam when completed will be 20 feet high in the center, and the reservoir when filled will have a surface area of 388 acres.

A. W. Mann: Claim in SE. $\frac{1}{4}$ sec. 31, T. 152, R. 104. He purposes to obtain water from draws in the bluffs behind.

Sarah and Kate Mercer: Desert claims on NW. $\frac{1}{4}$ sec. 32, and NE. $\frac{1}{4}$ sec. 31, T. 152, R. 104. They obtain water from draws. The main ditch to control these areas is already constructed.

BUFORD-TRENTON FLATS.

On the Buford-Trenton flats Mr. Edwin Jack (post-office, Trenton) has been foremost in the effort to secure water for irrigation. Associated with him are Carl Wittmeier, Grant Conley, and Charles Schumaker. A dam on Eightmile Creek, which comes down from the north and spreads out over the Missouri bottom lands 3 miles west of Trenton, has been constructed across the creek bed. The reservoir so formed has a surface area of 75.4 acres, and a capacity of 521.5 acre-feet. The dam, which is of earth faced with stone, has a suitable flume and waste gate. Its present capacity is regarded as sufficient, aided by the rainfall and inflow during the irrigating season, to care for 400 acres. The dam has washed out twice and has been rebuilt each time in a more substantial manner. Up to the present about $8,000 have been expended on reservoir and ditches, with results which have satisfied the owners that the outlay is justified. The capacity of this reservoir could be increased considerably without great expense, and it is probable that water from Eightmile Creek would still fill it if its capacity were not much above 1,000 acre-feet.

MUDDY RIVER FLATS.

The most notable attempt to irrigate in the vicinity of Williston was made a few years ago by Mr. Fred Rounsaville of that place. Ten miles above Williston, in sec. 5, T. 153, R. 100, he constructed a dam to divert the water from the stream and throw it into a lateral ditch, which would irrigate the flats on the right bank of the Muddy, and possibly a portion of the flats at its mouth on the Missouri. No attempt to store the water was included in the plan. The dam was constructed and a portion of the ditch, when the work was stopped by the death of Mr. Rounsaville. The property is now offered for sale.

On the Muddy above Williston and on its tributaries the following irrigation work is in progress, the operations for the most part being limited to spring flooding for grass:

George Marelius and Stephen A. Marmon have a reservoir in T. 151, R. 101, on Blacktail Creek, a tributary of the Muddy from the west. They are said to be flooding 1,200 acres for both grass and grain.

The Freeman family are constructing a reservoir on the upper course of the Muddy, in secs. 20, 23, 29, and 30, T. 158, R. 100, where they are planning to irrigate 1,900 acres.

Ellen Adams has a desert-land claim, which is now proved up, in secs. 28 and 29, T. 155, R. 98. Water is taken from coulees that are dry in summer, and the irrigation is for grass only.

Joseph Langford is irrigating 300 acres in secs. 21 and 27, T. 157, R. 100, on the upper Muddy.

F. R. Zahl and his family hold a section, which he irrigates for grass, in secs. 24 and 25, T. 159, R. 101, at the mouth of Scoria Creek, a tributary of the Muddy.

L. L. and Howard Lampman irrigate two sections on Cow Creek, a tributary of the Muddy, in T. 156, R. 102.

James Sherry, on Stump Creek, a tributary of the Muddy from the west, irrigates a 20-acre garden in sec. 2, T. 156, R. 102, by pumping from a reservoir in the creek. During the year 1903 he pumped only 4 days, this, with the rains, being enough to mature a full crop of garden truck. An 8-horsepower gasoline engine lifted 800 barrels an hour 20 feet. With gasoline at 30 cents a gallon, the cost of operation per day of 10 hours was $3. The owner estimates that with the rain of an ordinary year to assist, his plant is capable of irrigating 160 acres. The soil is a sandy loam with clay subsoil. The cost of pump, pipes, and engine delivered at Williston was $811. Mr. Sherry has great faith in the profit to be derived from the enterprise, and next year will extend the area that he irrigates.

Mr. E. A. Sharp, on his farm 2 miles northeast of Williston, in secs. 17 and 20, T. 154, R. 100, is installing a 10-horsepower gasoline engine and a centrifugal pump, which, for his lift of 10 feet, has a claimed capacity of 735 gallons a minute. He intends to irrigate for grass and grain. Water will be taken from Stony Creek and Muddy River. He estimates that he can irrigate 200 acres with his plant, and that 30 days will be a maximum time for operation in an ordinary year.

Joseph Langford has 320 acres in secs. 21 and 27, T. 157, R. 100, which he irrigates from the Muddy.

The Hedderick ranch (formerly the Voss) irrigates extensively for grass at the mouth of Cow Creek, on the Muddy flats.

R. M. Calderwood, Grant Greenup, Francis Hendrickson, and others have filed desert-land claims on Camp Creek, in T. 151, R. 102, and have made preparations to irrigate extensively.

LITTLE KNIFE FLATS.

Mr. Black has irrigated with profit for grass at the mouth of Little Knife Creek for a number of years.

NESSON-HOFFLUND FLATS.

The Nelson ranch, at the mouth of Nelson Creek, on the upper terrace at that point, is an illustration of the possibility of irrigating like land at a moderate cost from the creeks coming down from the upland. An earth dam at the mouth of Nelson Creek diverts the water and laterals spread it over a considerable area so that 600 acres or more are flooded in the spring. The ground is thoroughly soaked to a depth of 2 feet and is then allowed to stand a week before cultivation. On land so prepared oats often yield 60 bushels to the acre and wheat 25, while the surrounding country, as favorably located except for the flooding, yields from nothing to 10 bushels.

Wm. A Lamb.

One of the earliest attempts at irrigation in North Dakota was made at the old Grinnell ranch, at the mouth of Beaver Creek, where by dams and ditches the water from the creek was spread over several hundred acres of the lower Hofflund flat. Part of the same area is irrigated in the same way by H. A. Carey. Carey's dam is 20 feet high and is not intended to store water in the creek bed back of it to any considerable extent but to divert it to the laterals during the abundant water supply of the spring.

Ole Barsted has a dam and ditch on Dry Fork Creek, near its junction with the Beaver. Higher up on this creek are the dams of Wallender and Manly Anderson.

Nels J. Camp, William Barsted, and George Littlefield are diverting water for irrigation on Beaver Creek above Carey's.

Ward is irrigating the east end of the lower flat at Hofflund, at the old Lampman ranch.

HANCOCK FLATS.

Mr. F. G. Mattoon is putting in an extensive pumping plant to irrigate a portion of the fine flats on the Missouri at Hancock.

HEART RIVER FLATS.

Fisher Brothers, on Green River, a small tributary of the Heart, 7 miles north of Dickinson, have irrigated for two years, pumping water from the river. The lift is 15 feet, and a centrifugal pump with a discharge pipe having an inside diameter of 8 inches is used. A temporary dam 10 inches high and 30 feet long was thrown across the river in 1901 and retained all the water needed to irrigate 40 acres. In 1902 an abundance of rain made irrigation unnecessary. With this pump, which is driven by an ordinary farm engine, 1,500 gallons per minute are easily raised 15 feet. The cost of the pump delivered was $250. Mr. Fisher estimates that even in a dry season he would have no difficulty in irrigating 200 acres with his present equipment. Two dollars worth of coal was burned per day, coal costing 50 cents per ton at a neighboring bank.

Mr. A. F. Riley, on Heart River, near Gladstone, last year irrigated 20 acres by means of a dam thrown across a draw. Next year he proposes to irrigate 60 acres by means of a centrifugal pump. Lignite occurs on his farm, outcropping in a 4-foot seam, and can be had for the mere labor of mining.

RECOMMENDATIONS.

Opportunities to reclaim arid lands appear to exist in the larger flats on Missouri River. Much of the land in these flats is, however, already in private ownership, that lying within the Fort Berthold Reservation forming the only exception.

In choosing among the Missouri River flats for one where reclamation by pumping may be tried under most favorable conditions, a number of factors must be kept in mind. Nearness to a railroad and a market are as essential as an abundance of cheap fuel and good land. An active interest on the part of the resident owners is necessary where the land is already in part or wholly private property.

With these conditions in mind, the Buford-Trenton flats and the Nesson-Hofflund tract deserve first consideration. The former lie directly on the railroad, but lignite is not abundant near by and will cost about $2 per ton, whether mined in the vicinity or hauled from Williston. The Nesson-Hofflund flats are 14 miles from a railroad and are wholly in private ownership, but, on the other hand, lignite is very abundant near them and should be laid down at the pumping plant for $1 per ton; it may even be possible to locate a pumping plant within a few hundred yards of an extensive outcrop. From an engineering point of view, the Buford-Trenton tract appears so offer simpler conditions.

ACKNOWLEDGMENTS.

The writer was assisted in the field by Messrs. Hinds, Holgate, Pease, and Goodall, students at the University of North Dakota, and by Prof. L. H. Wood, under whose direction much of the work along Little Missouri and Heart rivers was carried on.

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