

GEOLOGICAL SURVEY CIRCULAR 159



# LIGNITE RESOURCES OF SOUTH DAKOTA

By Donald M. Brown

UNITED STATES DEPARTMENT OF THE INTERIOR  
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GEOLOGICAL SURVEY  
W. E. Wrather, Director

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## PREFACE

This report on the lignite resources of South Dakota is the sixth of a series of State summary reports prepared by the Geological Survey as part of a program to re-appraise the coal reserves of the United States. Summary studies of the reserves in other states are contained in the following publications: Geology of the Deep River coal field, Chatham, Lee, and Moore Counties, North Carolina, Preliminary Map, 1949; Coal resources of Montana, Circular 53, 1949; Coal resources of Michigan, Circular 77, 1950; Coal resources of Wyoming, Circular 81, 1950; and Coal resources of New Mexico, Circular 89, 1950.

W. E. Wrather,  
Director

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# LIGNITE RESOURCES OF SOUTH DAKOTA

## INTRODUCTION

This summary report on the lignite resources of South Dakota has been prepared as part of the program of the Department of the Interior for the integrated development of the Missouri River basin. It is based on a study of all information on the occurrence of lignite in South Dakota contained in the publications and files of the U. S. Geological Survey and the South Dakota Geological Survey, supplemented by a considerable amount of mine and drill-hole information provided by operating companies and private individuals.

Because large areas in the lignite fields of South Dakota have not been explored adequately for lignite, the estimates of reserves presented in this report are conservative, and are subject to revision upward as new work is completed in the future.

The author wishes to express his appreciation to Dr. E. P. Rothrock, State Geologist of South Dakota, who granted the use of the files and facilities of the South Dakota Geological Survey, and who offered many helpful suggestions for conducting the investigation; and to Mr. J. R. Lerwill of the Conservation Division of the Geological Survey and Mr. M. Clair Smith, State Mine Inspector of South Dakota, both of whom supplied much useful information.

## SUMMARY

The South Dakota lignite field covers an area of about 7,700 sq mi in the northwestern part of the State. (See fig. 1 and pl. 1.) The original reserves of lignite in this area are estimated to be 2,033 million tons as shown in tables 1 and 2, and the remaining, recoverable reserves as of January 1, 1951, are estimated to be 1,015 million tons. Of the total estimated reserves 83.6 percent is contained in Harding County, 9.2 percent in Perkins County, 6.8 percent in Dewey County, and the small remaining amount is divided between Ziebach, Meade, and Corson Counties. (See fig. 2.)

A large percentage of the South Dakota lignite reserves is contained in thin beds. Of the total estimated tonnage, 63 percent is in beds ranging from 2.5 to 5 ft in thickness, 34 percent in beds 5 to 10 ft thick, and only 3 percent in beds more than 10 ft thick. This is in marked contrast to the distribution of reserves in states to the north and west where a large percentage of the total reserves is in the thicker beds.

The lignite beds of South Dakota are flat lying over large areas, but locally dip gently on the flanks of small, inconspicuous folds that would be no hindrance to mining. All of the reserves are less than 1,000 ft below the surface. Although no attempt was made to determine reserves in intermediate categories of overburden, as much as

80 percent of the total tonnage may be under less than 500 ft of overburden. A number of areas in which the lignite is under cover thin enough to permit stripping operations are discussed in the text.

A breakdown of the reserves into categories based on the relative abundance and reliability of information shows that 84 percent of the total is classed as indicated reserves, compared to 7 percent measured reserves and 9 percent inferred reserves. (See fig. 2.) The unusually low percentage of measured reserves as compared with the indicated reserves is due to the fact that in South Dakota the lignite of minable thickness normally occurs in small lenses, and that the points of observation are widely spaced and confined mostly to outcrop measurements.

Of the estimated original reserves of 2,033 million tons of lignite in South Dakota, reported mine production through December 31, 1950, totals 989,361 tons (see table 3, fig. 3), and mining losses are assumed to have been approximately equal to that figure. Subtracting from the original reserves the lignite mined and lost in mining, the remaining reserves as of January 1, 1951, were 2,031 million tons. Assuming that mining losses in the future will be 50 percent, recoverable reserves of the State, as of January 1, 1951, are estimated at 1,015 million tons.

Bituminous coal is found in small areas in Fall River County in the southwestern part of the State, the total reserve of minable thickness being estimated at 10,900 tons. This quantity is so small that it is not included in the tables of reserves, although it is discussed in the text.

## METHODS OF ESTIMATING RESERVES

Any estimate of the coal reserves in an area as large as a state is necessarily based on many assumptions as to thickness, extent, and correlation of the coal beds and other pertinent factors. Therefore an estimate is of value to the reader only to the extent that the definitions and procedures under which the estimate was prepared are explained and understood. In this report, the estimates are broken down into categories based on the characteristics of the coal, and on the abundance and reliability of the available information. The definitions and methods used are described briefly in the following paragraphs. They are essentially those used in other state summaries recently published by the Geological Survey, with such minor modifications as local conditions dictate.

### Classification according to characteristics of the coal

Characteristics considered in calculating coal reserves are the rank of the coal, the thickness of the beds, and the thickness of the overburden. The weight of the coal, necessarily the starting point in

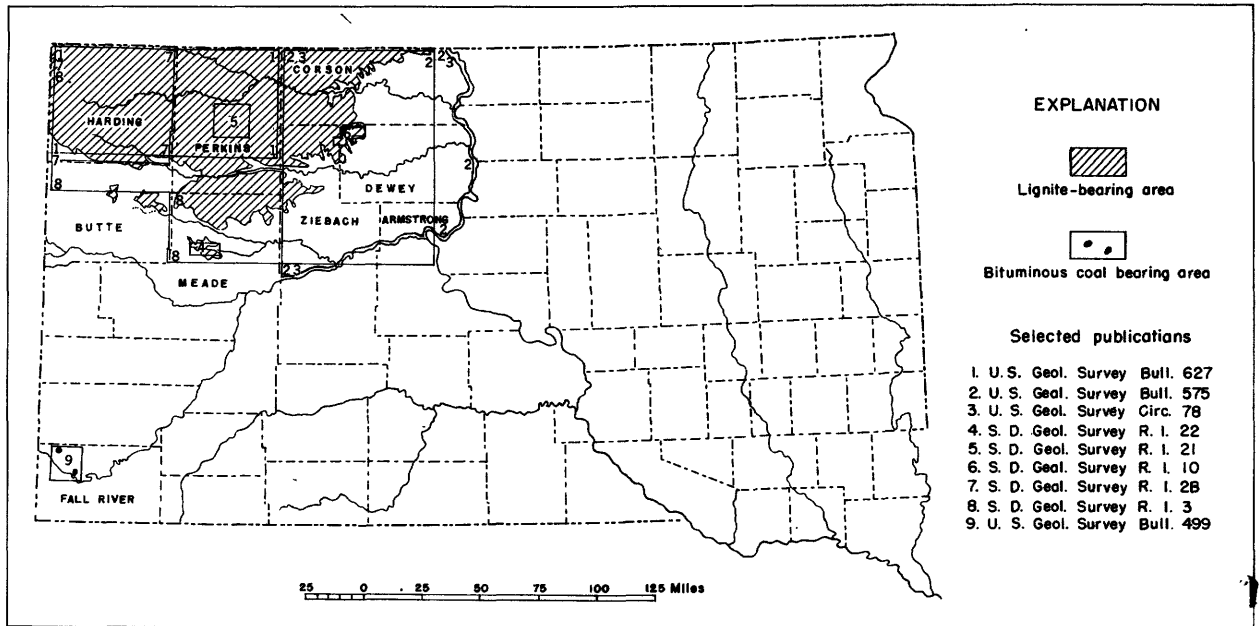


Figure 1. --Index map of South Dakota showing bituminous coal and lignite areas, and portions covered by selected publications.

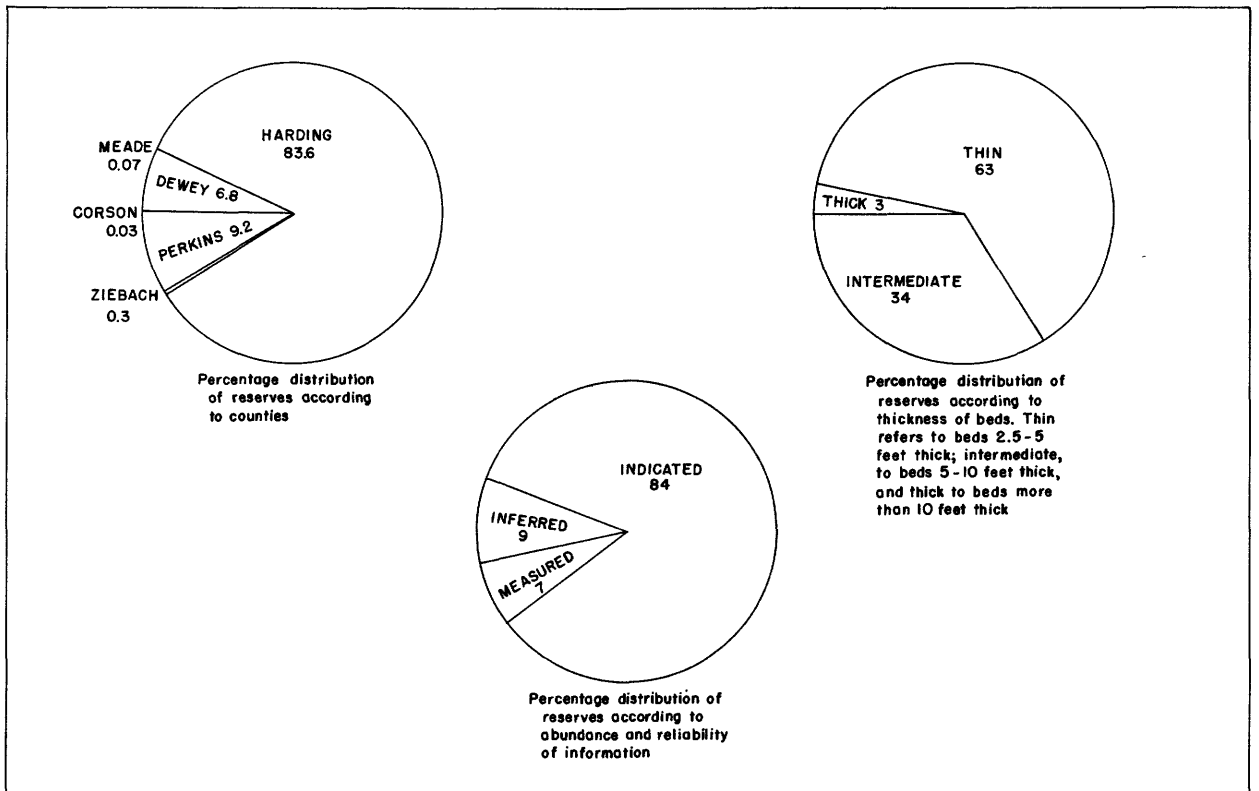


Figure 2. --Percentage distribution of South Dakota lignite reserves according to counties, thickness of beds, and abundance and reliability of information.

Table 1.--Original reserves of lignite in South Dakota under less than 1,000 ft of overburden, by townships and counties  
(in millions of short tons)

Township	Measured reserves				Indicated reserves				Inferred reserves				Total in all categories				Township total
	In beds 2 1/2 ft to 5 ft thick		In beds more than 5 ft to 10 ft thick		In beds 2 1/2 ft to 5 ft thick		In beds more than 5 ft to 10 ft thick		In beds 2 1/2 ft to 5 ft thick		In beds more than 5 ft to 10 ft thick		In beds 2 1/2 ft to 5 ft thick		In beds more than 5 ft to 10 ft thick		
	Total	0.02	Total	0.02	Total	0.02	Total	0.02	Total	0.02	Total	0.02	Total	0.02	Total	0.02	
<u>Gorsion County</u>																	
T.16N., R.20E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.20E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.19N., R.21E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.21E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.21E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.22E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
County total	.....	0.54	.....	0.02	.....	0.56	.....	.....	.....	.....	.....	.....	.....	0.54	0.02	.....	0.56
<u>Dewey County</u>																	
T.16N., R.22E.	17.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.17N., R.22E.	60.25	5.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.17N., R.23E.	27.17	27.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
County total	104.42	33.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	104.42	33.68	.....	138.10
<u>Harding County</u>																	
T.19N., R.1E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.1E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.1E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.1E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.2E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.2E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.2E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.3E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.4E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.4E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.4E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.5E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.5E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.6E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.17N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.18N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.19N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.20N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.21N., R.7E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
County total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....



T.22N., R.7E.	.....	.....	.....	.....	.....	26.41	95.04	.....	.....	120.71	0.74	.....	121.45
T.23N., R.7E.	.....	.....	.....	.....	.....	13.99	.....	.....	.....	13.99	.....	.....	13.99
T.16N., R.8E.	.....	.....	.....	.....	.....	17.51	.....	.....	.....	17.51	1.11	.....	17.51
T.17N., R.8E.	.....	.....	.....	.....	.....	59.55	.....	.....	.....	59.55	34.60	.....	59.55
T.19N., R.8E.	.....	.....	.....	.....	.....	31.51	.....	.....	.....	31.51	1.42	1.10	34.03
T.20N., R.8E.	.....	.....	.....	.....	.....	26.83	.....	.....	.....	26.83	42.21	.....	69.07
T.21N., R.8E.	.....	.....	.....	.....	.....	111.43	.....	.....	.....	111.43	33.52	2.99	147.94
T.22N., R.8E.	.....	.....	.....	.....	.....	61.36	.....	6.48	.....	67.84	93.13	19.48	180.45
T.23N., R.8E.	.....	.....	.....	.....	.....	15.16	.....	.....	.....	15.16	.58	.....	15.74
T.19N., R.9E.	.....	.....	.....	.....	.....	7.31	.....	.....	.....	7.31	1.72	.....	9.03
T.20N., R.9E.	.....	.....	.....	.....	.....	16.20	.....	.....	.....	16.20	18.77	.....	35.20
T.21N., R.9E.	.....	.....	.....	.....	.....	14.20	.....	.....	.....	14.20	.....	.....	14.20
T.22N., R.9E.	.....	.....	.....	.....	.....	7.74	.....	.....	.....	7.74	.....	.....	7.74
T.23N., R.9E.	.....	.....	.....	.....	.....	1.18	.....	.....	.....	1.18	.....	.....	1.18
County total	.....	.....	.....	.....	843.40	51.49	1,523.01	177.29	0.06	1,020.69	628.18	51.49	1,700.36

Meade County

T.9N., R.12E.	.....	.....	.....	.....	.....	1.38	.....	.....	.....	1.38	.....	.....	1.38
County total	.....	.....	.....	.....	.....	1.38	.....	.....	.....	1.38	.....	.....	1.38

Ferkins County

T.17N., R.10E.	.....	.....	.....	.....	.....	1.14	.....	.....	.....	1.14	.....	.....	1.14
T.18N., R.10E.	.....	.....	.....	.....	.....	6.69	.....	.....	.....	6.69	.....	.....	6.69
T.19N., R.10E.	.....	.....	.....	.....	.....	29.77	.....	.....	.....	28.52	1.25	.....	29.77
T.20N., R.10E.	.....	.....	.....	.....	.....	7.46	.....	.....	.....	7.46	.....	.....	7.46
T.22N., R.10E.	.....	.....	.....	.....	.....	1.22	.....	.....	.....	.93	.29	.....	1.22
T.23N., R.10E.	.....	.....	.....	.....	.....	1.57	.....	.....	.....	1.57	.....	.....	1.57
T.17N., R.11E.	.....	.....	.....	.....	.....	2.69	.....	.....	.....	2.69	.....	.....	2.69
T.18N., R.11E.	.....	.....	.....	.....	.....	1.01	.....	.....	.....	1.01	.....	.....	1.01
T.19N., R.11E.	.....	.....	.....	.....	.....	34.99	.....	.....	.....	33.15	1.84	.....	34.99
T.20N., R.11E.	.....	.....	.....	.....	.....	8.22	.....	.....	.....	8.22	.....	.....	8.22
T.21N., R.11E.	.....	.....	.....	.....	.....	.85	.....	.....	.....	.85	.85	.....	.85
T.22N., R.11E.	.....	.....	.....	.....	.....	51	.....	.....	.....	51	.51	.....	51
T.17N., R.12E.	.....	.....	.....	.....	.....	6.66	.....	.....	.....	6.66	.....	.....	6.66
T.18N., R.12E.	.....	.....	.....	.....	.....	2.17	.....	.....	.....	2.17	.....	.....	2.17
T.19N., R.12E.	.....	.....	.....	.....	.....	6.34	.....	.....	.....	6.34	.....	.....	6.34
T.21N., R.12E.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
T.22N., R.12E.	.....	.....	.....	.....	.....	27.20	.....	.....	.....	.....	27.20	.....	27.20
T.23N., R.12E.	.....	.....	.....	.....	.....	6.34	.....	.....	.....	6.34	6.34	.....	6.34
T.17N., R.13E.	.....	.....	.....	.....	.....	17.91	.....	.....	.....	17.91	.61	.....	17.91
T.19N., R.13E.	.....	.....	.....	.....	.....	.44	.....	.....	.....	.44	.....	.....	.44
T.22N., R.13E.	.....	.....	.....	.....	.....	.33	.....	.....	.....	.33	5.77	.....	.33
T.23N., R.13E.	.....	.....	.....	.....	.....	8.19	.....	.....	.....	8.19	.....	.....	8.19
T.17N., R.14E.	.....	.....	.....	.....	.....	2.28	.....	.....	.....	2.28	.....	.....	2.28
T.20N., R.14E.	.....	.....	.....	.....	.....	2.13	.....	.....	.....	2.13	.....	.....	2.13
T.21N., R.14E.	.....	.....	.....	.....	.....	.77	.....	.....	.....	.77	.....	.....	.77
T.22N., R.14E.	.....	.....	.....	.....	.....	.15	.....	.....	.....	.15	.....	.....	.15
T.20N., R.15E.	.....	.....	.....	.....	.....	3.20	.....	.....	.....	3.20	.....	.....	3.20
T.21N., R.15E.	.....	.....	.....	.....	.....	2.60	.....	.....	.....	2.60	.....	.....	2.60
T.17N., R.17E.	.....	.....	.....	.....	.....	2.91	.....	.....	.....	2.91	.....	.....	2.91
County total	.....	.....	.....	.....	141.85	186.51	.....	.....	.....	141.85	44.66	.....	186.51

Table 1.--Original reserves of lignite in South Dakota under less than 1,000 ft of overburden, by townships and counties  
(in millions of short tons)--Continued

Township	Measured reserves				Indicated reserves				Inferred reserves				Total in all categories			
	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds 10 ft thick	Total	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds 10 ft thick	Total	In beds 5 to 10 ft thick	In beds 10 ft thick	In beds more than 10 ft thick	Total	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds more than 10 ft thick	Township total
T.16N., R.21E.	....	....	....	....	5.31	0.69	....	6.00	....	....	....	....	5.31	0.69	....	6.00
County total	....	....	....	....	5.31	0.69	....	6.00	....	....	....	....	5.31	0.69	....	6.00
State total	104.42	33.68	....	138.10	992.48	673.49	51.49	1,717.46	177.29	0.06	....	177.35	1,274.19	707.23	51.49	2,032.91

Ziebach County

Table 2.--Original reserves of lignite in South Dakota, by counties  
(in millions of short tons)

County	Measured reserves				Indicated reserves				Inferred reserves				Total in all categories			
	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds 10 ft thick	Total	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds 10 ft thick	Total	In beds 5 to 10 ft thick	In beds 10 ft thick	In beds more than 10 ft thick	Total	In beds 2 1/2 to 5 ft thick	In beds 5 to 10 ft thick	In beds more than 10 ft thick	County total
Corson	....	....	....	....	0.54	0.02	....	0.56	....	....	....	....	0.54	0.02	....	0.56
Dewey	104.42	33.68	....	138.10	....	....	....	....	....	....	....	....	104.42	33.68	....	138.10
Harding	....	....	....	....	843.40	628.12	51.49	1,523.01	177.29	0.06	....	177.35	1,020.69	628.18	51.49	1,700.36
Meade	....	....	....	....	1.38	....	....	1.38	....	....	....	....	1.38	....	....	1.38
Perkins	....	....	....	....	141.85	44.66	....	186.51	....	....	....	....	141.85	44.66	....	186.51
Ziebach	....	....	....	....	5.31	.69	....	6.00	....	....	....	....	5.31	.69	....	6.00
State total	104.42	33.68	....	138.10	992.48	673.49	51.49	1,717.46	177.29	0.06	....	177.35	1,274.19	707.23	51.49	2,032.91

Table 3.--Lignite production in South Dakota, 1913-50, by counties 1/

Year	County						Total
	Corson	Dewey	Harding	Meade	Perkins	Ziebach	
1913	....	1,040	(3)	575	8,925	....	10,540
1914	....	5,142	(3)	625	6,083	....	11,850
1915	....	5,645	(3)	400	4,548	....	10,593
1916	....	2,326	(3)	781	5,779	(3)	8,886
1917	....	3,092	(3)	995	3,955	(3)	8,042
1918	....	2,579	(3)	645	4,718	(3)	7,942
1919	....	5,991	(3)	824	7,602	(3)	14,417
1920	....	6,119	(3)	5/ 650	6,008	(6)	12,777
1921	....	1,891	(3)	5/ 791	4,871	(6)	7,553
1922	....	1,330	(3)	4/ 937	5,485	(6)	7,752
1923	....	2,325	(3)	2/ 586	7,468	(6)	10,379
1924	....	....	5/ 3,819	1,539	6,685	(8)	12,043
1925	....	4,200	....	5/ 5,120	5,127	(6)	14,447
1926	2/ 408	5,020	(9)	1,537	5,763	1,700	14,428
1927	2/ 720	3,775	(9)	3,250	4,762	(6)	12,507
1928	700	6,863	(9)	1,690	4,676	(6)	13,929
1929	(3)	4,716	(6)	2,243	5,895	(3)	12,854
1930	5/ 625	3,880	875	1,500	5,930	(9)	12,810
1931	993	18,800	1,030	1,116	5,546	(9)	27,485
1932	3,246	35,726	1,680	1,255	7,167	(9)	49,074
1933	7,395	43,970	(9)	1,059	6,951	(9)	59,375
1934	3,210	30,375	1,485	1,448	5,889	(9)	42,407
1935	(3)	5,162	(3)	1,558	6,523	....	13,243
1936	....	2/ 33,136	(3)	1,616	6,579	....	41,331
1937	....	2/ 41,718	(3)	972	4,289	....	46,979
1938	(3)	11/ 43,164	(3)	1,176	3,718	....	48,058
1939	(3)	12/ 44,907	(6)	1,671	2,917	....	49,495
1940	(3)	12/ 61,077	(6)	2/ 1,809	3,199	....	66,085
1941	(3)	12/ 65,730	(6)	2/ 2,127	2,968	....	70,825
1942	(3)	12/ 48,226	(6)	1,859	3,453	....	53,538
1943	(3)	12/ 38,909	(6)	1,755	....	....	40,664
1944	(3)	13/ 22,887	(14)	(3)	3,940	....	26,827
1945	....	17,092	1,833	....	2/ 5,520	....	24,445
1946	1,370	13,029	....	....	2,547	....	16,946
1947	....	10,427	....	....	4,191	....	14,618
1948	1,804	27,290	....	....	....	....	29,094
1949	(15)	(15)	(15)	(15)	(15)	(15)	26,429
1950	(15)	(15)	(15)	(15)	(15)	(15)	16/ 38,694
Total	20,471	667,559	10,722	44,109	179,677	1,700	989,361

1/ Production, 1913 through 1923, from U. S. Geological Survey Mineral Resources of the United States, annual volumes; production, 1924 through 1950, from U. S. Bureau of Mines Minerals Yearbooks.

- 2/ Includes Harding County.
- 3/ Included with Dewey County.
- 4/ Includes Harding and Ziebach Counties.
- 5/ Includes Ziebach County.
- 6/ Included with Meade County.
- 7/ Includes Ziebach County and wagon mines.
- 8/ Included with Harding County.
- 9/ Included with Corson County.
- 10/ Includes Corson and Ziebach Counties.
- 11/ Includes Corson and Harding Counties.
- 12/ Includes Corson County.
- 13/ Includes Corson and Meade Counties.
- 14/ Included with Perkins County.
- 15/ Production figures by counties not available.
- 16/ Includes a small amount of production in California.

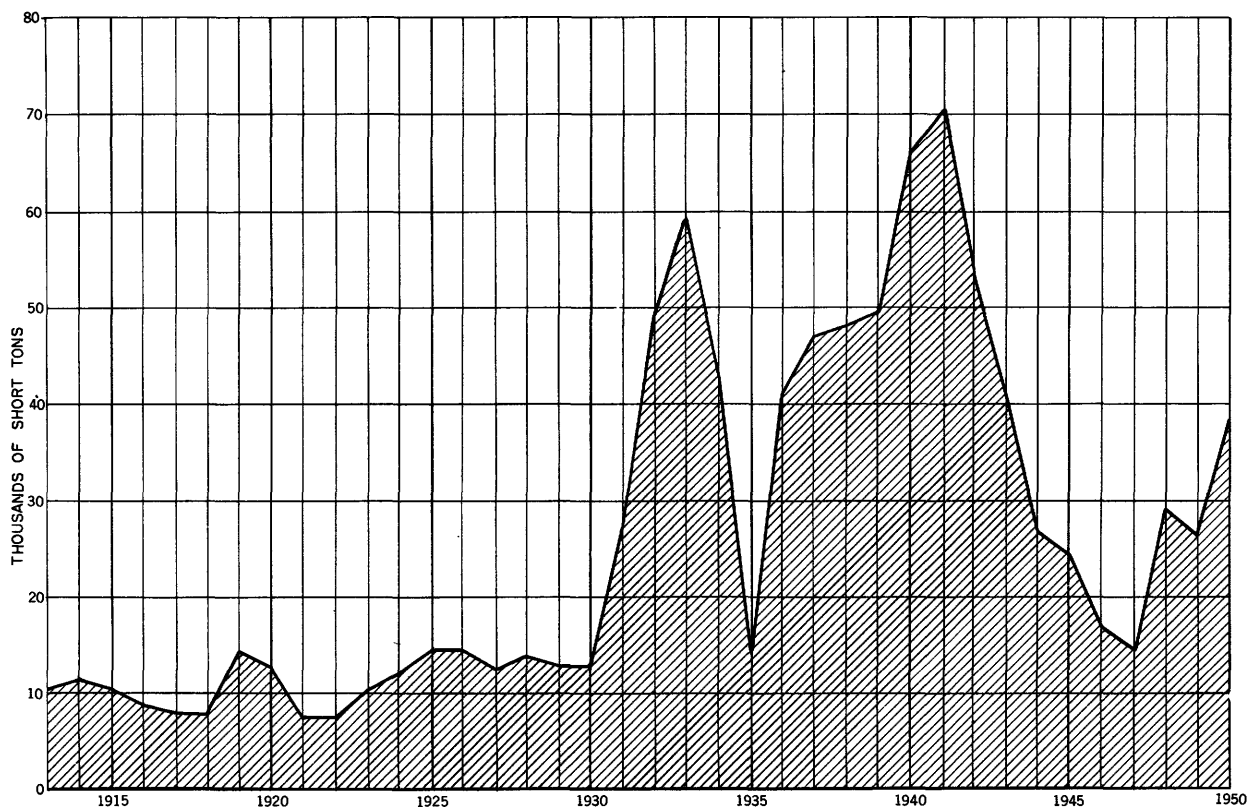


Figure 3. --Lignite production in South Dakota, 1913-50. (Data from U. S. Geological Survey, Mineral Resources of the United States, annual volumes, 1913-23; U. S. Bureau of Mines, Minerals Yearbook, 1924-50).

tonnage calculations, is to a large extent a function of the rank.

**Rank of coal.** --With the exception of a small quantity of bituminous coal, which is discussed in a later section of this report, but which is not included in the reserve tables, all coal in South Dakota is ranked as lignite under the Standard Classification of the American Society for Testing Materials. This classification is reproduced as table 4, and analyses of a number of samples of South Dakota lignite are given in table 5.

**Weight of coal.** --The average weight of lignite, as determined by numerous specific gravity determinations of samples from different parts of the United States, is 1,750 tons per acre-foot. This weight has been used uniformly in calculating South Dakota lignite reserves.

**Thickness of beds.** --In order to provide as much information as possible on the distribution of reserves, all estimates prepared by the Geological Survey classify coal resources as thin, intermediate, and thick beds. For lignite and subbituminous coal, beds 2.5 to 5.0 ft thick are classed as thin; from 5 to 10 ft as intermediate; and more than 10 ft as thick. These thicknesses are higher than those used for bituminous coal and anthracite, which are from 14 to 28 in., from 28 to 42 in., and more than 42 in. respectively.

**Thickness of overburden.** --The coal resources publications of the U. S. Geological Survey divide the

reserves into three overburden categories; less than 1,000 ft, 1,000 to 2,000 ft, and 2,000 to 3,000 ft; no coal more than 3,000 ft below the surface is included in reserve estimates. In South Dakota, the known coal is everywhere less than 1,000 ft below the surface. It appears likely, on the basis of reconnaissance work in the lignite fields, that as much as 80 percent of the reserves are under less than 500 ft of cover; however, little detailed stratigraphic information is available, and for that reason no attempt is made in this report to break down the reserves into depth-of-cover categories other than to place all of the tonnage in the less-than-1,000-foot category.

The lignite beds are essentially flat lying, the topographic relief is moderate, and the numerous small structures in the coal-bearing area are too small to interfere in any important way with mining. For these reasons the beds may be mined by striping in many localities. Although it was not possible to prepare an estimate of reserves suitable for strip mining, a few areas where the opportunities for strip mining appeared to be favorable are discussed in a later section of this report.

#### Classification according to abundance of data

Coal reserves are divided, according to the relative abundance and reliability of the data upon which estimates are based, into three categories, termed measured, indicated, and inferred reserves.

**Measured reserves.** --Measured reserves are those for which data are sufficiently abundant and

Table 4. Classification of coals by rank<sup>a</sup>

Legend: F.C. = Fixed Carbon.

V.M. = Volatile Matter.

Btu. = British thermal units.

Class	Group	Limits of Fixed Carbon or Btu. Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite.....	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	Nonagglomerating <sup>b</sup>
	2. Anthracite.....	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semianthracite.....	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	
II. Bituminous <sup>d</sup>	1. Low volatile bituminous coal....	Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent)	Either agglomerating or nonweathering <sup>f</sup>
	2. Medium volatile bituminous coal.	Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent)	
	3. High volatile A bituminous coal.	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist <sup>c</sup> Btu., 14,000 <sup>e</sup> or more	
	4. High volatile B bituminous coal.	Moist <sup>c</sup> Btu., 13,000 or more and less than 14,000 <sup>e</sup>	
	5. High volatile C bituminous coal.	Moist Btu., 11,000 or more and less than 13,000 <sup>e</sup>	
III. Subbituminous	1. Subbituminous A coal.....	Moist Btu., 11,000 or more and less than 13,000 <sup>e</sup>	Both weathering and nonagglomerating
	2. Subbituminous B coal.....	Moist Btu., 9500 or more and less than 11,000 <sup>e</sup>	
	3. Subbituminous C coal.....	Moist Btu., 8300 or more and less than 9500 <sup>e</sup>	
IV. Lignitic	1. Lignite.....	Moist Btu., less than 8300	Consolidated Unconsolidated
	2. Brown coal.....	Moist Btu., less than 8300	

<sup>a</sup> This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

<sup>b</sup> If agglomerating, classify in low-volatile group of the bituminous class.

<sup>c</sup> Moist Btu. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

<sup>d</sup> It is recognized that there may be noncaking varieties in each group of the bituminous class.

<sup>e</sup> Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

<sup>f</sup> There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and nonweathering; Variety 2, agglomerating and weathering; Variety 3, nonagglomerating and nonweathering.

Table 5.--Selected analyses of South Dakota lignite -- as-received basis

Location	Bureau of Mines Laboratory Number	Formation Member	Bed	Proximate Analysis				Ultimate Analysis				Air-Drying Loss	B. t. u.	
				Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen			Oxygen
<b>Corson County</b>														
1. Sec. 19, T. 21N., R. 21E.	7840	Hell Creek	Unnamed	30.50	23.00	34.40	12.10	0.39	.....	.....	.....	.....	19.7	6,940
<b>Dewey County</b>														
Isabel Firesteel field:														
2. Sec. 18, T. 17N., R. 23E.	C75362	Hell Creek	Firesteel	36.50	27.30	29.80	6.40	.50	.....	.....	.....	.....	.....	7,020
<b>Harding County</b>														
Cave Hills field:														
3. Sec. 6, T. 20N., R. 5E.	13221	Ludlow	Hilton	39.80	25.30	23.80	11.10	.96	.....	.....	.....	.....	33.0	5,480
4. Sec. 20, T. 21N., R. 7E.	---	Ludlow	Giannonatti	40.85	23.80	26.36	8.99	.90	.....	.....	.....	.....	..	5,791
5. Sec. 10, T. 20N., R. 9E.	15062	Ludlow	Widow Clark	34.70	27.20	29.00	9.10	.95	.....	.....	.....	.....	26.6	6,250
<b>Slim Buttes field:</b>														
6. Sec. 1, T. 16N., R. 7E.	A3557	Ludlow	Unnamed	41.00	23.20	28.40	7.40	2.20	7.00	37.80	0.50	45.10	..	6,380
7. Sec. 1, T. 17N., R. 7E.	13222	Ludlow	Unnamed	41.10	25.80	24.00	9.10	1.14	.....	.....	.....	.....	34.3	5,320
8. Sec. 1, T. 17N., R. 7E.	13220	Ludlow	Unnamed	41.50	24.00	24.30	10.20	.55	.....	.....	.....	.....	34.7	5,650
<b>Perkins County</b>														
9. Sec. 2, T. 17N., R. 10E.	12454	Ludlow	Unnamed	34.70	26.40	27.60	11.30	1.08	6.60	38.02	..	44.28	19.6	6,310
10. Sec. 35, T. 19N., R. 10E.	12453	Ludlow	Unnamed	39.20	24.70	27.80	8.35	2.22	7.07	35.22	.53	46.93	26.0	5,950
11. Sec. 7, T. 17N., R. 11E.	12408	Hell Creek	Unnamed	42.50	23.20	25.30	9.00	1.16	.....	.....	.....	.....	30.1	6,960
12. Sec. 29, T. 21N., R. 12E.	14354	Tongue River	Lodgepole	33.30	28.90	27.30	10.50	1.76	.....	.....	.....	.....	21.2	6,960
13. Sec. 20, T. 17N., R. 13E.	----	Ludlow	Unnamed	32.98	28.41	29.10	9.51	1.31	.....	.....	.....	.....	.....	7,075

Analysis 1 from Miscellaneous analyses of coal samples from various fields of the United States: U. S. Geol. Survey Bull. 471-J, p. 647, 1912.  
 Analysis 2 from U. S. Bureau of Mines.  
 Analysis 3, 5, and 7-12 from the lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, pp. 42-43, 1916.  
 Analysis 4 and 13 from A preliminary report of the coal resources of South Dakota: South Dakota Geol. and Nat. History Survey Rept. Inv. no. 3, pp. 26-27, 1930.  
 Analysis 6 from Analyses of Michigan, North Dakota, South Dakota, and Texas coals: U. S. Bur. Mines Tech. Paper 700, p. 56, 1918.

reliable for the estimates to be considered accurate within 20 percent of the actual tonnage. For measured coal, therefore, the points of information must be closely spaced; for South Dakota lignite, a spacing of half a mile or less between points of information is considered necessary to achieve measured-reserve accuracy. Because there are very few mine workings or drill holes in the South Dakota lignite fields, most of the data are derived from measurements of the lignite beds at the outcrop. Hence this criterion would normally limit the measured lignite to a band extending half a mile behind the outcrop and half a mile beyond the last point of information on the outcrop. Because of the lack of precise, closely spaced points of information for much of the State, measured reserves represent only 7 percent of the estimated total reserves.

Indicated reserves. --Indicated reserves are those for which points of information are spaced more widely than that for measured coal; in South Dakota, the spacing of measurements is about 1 mile. In areas where a bed is known to be relatively extensive, the limit of indicated coal is placed 2 miles behind the outcrop, or 2 miles from the farthest point of information. Thus, in South Dakota where most information is from outcrop measurements, the indicated coal will be contained normally in a band 2 miles wide unless there is measured coal at the outcrop, in which case the width of the band would be reduced to 1 1/2 miles because of the half-mile distance used for measured coal.

As few beds in South Dakota are continuous enough on the outcrop to justify the assumption that they are continuous underground beyond the 2-mile limit used for indicated coal, the bulk of the estimated South Dakota reserves (84 percent) is classed as indicated reserves. This is in marked contrast to most coal-bearing areas, where the largest tonnages normally fall in the inferred category.

Inferred reserves. --Inferred reserves include those for which points of information are more widely spaced than those required for the measured and indicated categories, and those which are believed to be present on the basis of geologic evidence, though few precise measurements are available. Because of the limited extent of lignite beds of minable thickness in South Dakota, as observed on the outcrops, and because of the small amount of information available about the occurrence of lignite at depth, the inferred reserves of the State as estimated herein constitute only 9 percent of the total tonnage. Many areas in the State have not been explored for lignite; however, and it is certain that additional mapping and exploratory work will make possible a larger estimate of reserves.

#### Distinction between original, remaining, and recoverable reserves

The estimates of reserves presented in this report are discussed from three points of view: as original reserves; remaining reserves as of January 1, 1951; or recoverable reserves as of January 1, 1951.

Original reserves. --The basic estimates in this report are of original reserves in the ground before mining, and include all known coal originally

present except that which has burned in place. The calculations were made on the basis of original reserves because the coal-bearing areas of South Dakota have never been mapped adequately, and it is therefore impossible to delineate mined-out areas; in fact, nearly all the information available on mining in the State is contained in the yearly production figures. However, as less than 0.05 percent of the State's estimated reserves have been mined, the estimate of original reserves can be used for practically all purposes without distorting the true picture. As shown in tables 1 and 2, the original lignite reserves of South Dakota are estimated at 2,033 million tons.

Remaining reserves. --The reported production in South Dakota since the beginning of large-scale mining in 1913 has been 989,361 tons. (See table 3.) Assuming mining losses to be 50 percent (Averitt and Berryhill, 1950, p. 8), which is the figure now commonly accepted as the average for the United States, coal mined and lost in mining is estimated at 1,978,722 tons, or which, subtracted from the original reserves of 2,033 million tons, leaves a reserve remaining as of January 1, 1951, of 2,031 million tons.

Recoverable reserves. --No figures showing the actual percentage of coal lost in mining in South Dakota are available. Most of the past mining in South Dakota, and in all probability most of the mining in the immediate future, will be by surface methods. Strip mining is usually accompanied by smaller mining losses than underground mining, some estimates showing recoverabilities as high as 85 or 90 percent and even higher; however, it is doubtful if such recoveries would apply throughout sizable coal fields, though they may be applicable to individual properties. For this reason the figure of 50 percent used by Averitt and Berryhill is adopted for this report. On that basis the recoverable reserves of South Dakota are 50 percent of the remaining reserves of 2,031 million tons, or 1,015 million tons. It is entirely possible that the relatively high recovery from strip mining may have the effect of increasing the recoverable reserves, as compared to the remaining reserves, of South Dakota; but in the absence of definite information on the subject, the conservative 50-percent figure, which has been applied in other states, is used also for South Dakota.

#### Methods of recording data and making calculations

All tonnages in this report were calculated by individual beds, using the township as the areal unit. Work maps were prepared on various scales, which were determined by available published maps or by the other data obtainable. On each map the outcrop of a single coal bed was traced, and all measured sections, drill holes, mine information, and other data pertaining to that bed were plotted on the same sheet. Isopach lines were drawn on the basis of the plotted information, dividing the lignite into the three thickness categories. Other lines were then drawn, breaking the deposit down into the measured, indicated, and inferred categories on the basis of the spacing of the data. As all of the lignite included in the estimates is less than 1,000 ft below the surface, and as sufficient information to break down the thickness of overburden into smaller units was not available, no overburden lines, such as are used in

most coal-estimate work, were necessary in this compilation.

The thickness of the lignite was obtained by taking a weighted average of all thickness figures from outcrop and mine measurements and from drill-hole logs. The thicknesses used are the actual thicknesses of lignite, disregarding partings, unless the partings exceed half the total thickness of the coal bed. In such cases the coal is considered to be of no value and therefore is not included in the estimate.

The lateral extent of the coal was determined mainly by the extent of the outcrop, as little drill-hole and mine data were available in the State. It was assumed that the coal extends as far back of the outcrop as it is exposed along the outcrop; and therefore an arc, having half the length of the outcrop as its radius, was drawn to delimit the coal to be included in the estimate. In many areas the arc was modified in the light of the shape of the outcrop, known thickening or thinning of the coal in short distances, or other local conditions. Because of the known lenticularity of the South Dakota lignite beds, all of the data were interpreted as conservatively as possible.

The areas outlined on the maps as described above were measured with a planimeter, and the acreage underlain by coal in the different thickness groups and reserve categories were thus obtained. The tonnage was calculated by multiplying together the number of acres, the thickness of the coal in feet, and 1,750, the weight in tons per acre-foot of the lignite. The figures were tabulated by township and county totals, and finally by the State total, broken down into thickness and abundance of information categories.

In making the actual calculations, figures were carried to the nearest 10,000 tons because some of the smaller deposits contain reserves of this order of magnitude. To facilitate machine calculation and later tabulation and checking, the reserves in the larger deposits were calculated to the same unit, as were township and county totals derived from these figures. From a practical point of view, however, the estimates for the larger deposits and the larger areas can be regarded as being significant only to the nearest million tons, which amount is indicated by a decimal point in all of the accompanying tables.

Areas covered by estimates. --The area underlain by lignite-bearing formations in northwestern South Dakota covers about 7,700 sq mi, and includes all or parts of 267 townships; it is outlined on the map (pl. 1), on which the areas for which reserve estimates are given are shown in green. It will be readily seen that the estimates cover only a small part of the total area underlain by lignite-bearing formations. This does not necessarily indicate the absence of lignite in many of the townships for which no estimates are given; but it reflects the lack of information on large parts of the South Dakota lignite fields. Generally speaking, however, there appears to be little likelihood that the southernmost townships underlain by lignite-bearing formations contain commercial quantities of lignite. In fact, workable beds probably are confined to the area north of the

line between Tps. 15 and 16 N. (See map, pl. 1.) It is doubtful, also, if much lignite exists in the eastern part of the area, in Dewey, Ziebach, and eastern Corson Counties, other than that shown on the map. On the other hand, it is probable that some of the townships in Harding County and the western part of Perkins County, which, because of the lack of information, are shown as containing no known minable lignite, actually may have considerable reserves of fairly thick lignite.

Limitations of estimates. --Because of the conditions pointed out in the preceding section the estimates given in this report are to be considered as provisional rather than final. Only in the Isabel-Firesteel area has the lignite been systematically prospected by drilling. When and if other parts of the State, particularly areas in Harding and Perkins Counties, are explored, it is practically certain that additional quantities of lignite will be discovered, and also that large reserves now classed as indicated and inferred will be moved into the measured category. The present estimate should thus be considered as a framework to which additional reserves may be added as new data are accumulated.

#### COMPARISON OF PAST AND PRESENT ESTIMATES

The only estimate of the lignite resources of South Dakota made prior to the present compilation is that of M. R. Campbell in the years prior to 1928 as reprinted by Averitt and Berryhill (1950). The Campbell estimate gave a total of 1,020 million tons, whereas the present estimate is almost exactly twice that figure, or 2,033 million tons. The two estimates, however, are not comparable. Since the Campbell estimate was made, new lignite-bearing areas have been explored in the Isabel-Firesteel area, and near Stoneville, and in the Standing Rock-Cheyenne Indian Reservation. In addition, the Campbell estimate was based on a minimum lignite thickness of 2 ft 10 in., whereas the minimum used in the present estimate is 2 ft 6 in. In view of the fact that 63 percent of the present estimate of reserves falls in the "thin" classification, it can readily be seen that the 4-inch difference in cut-off could make an appreciable difference in the tonnage figures.

#### GEOLOGY OF THE SOUTH DAKOTA LIGNITE FIELDS

The lignite-bearing portion of South Dakota is in the northwestern part of the State and includes parts of Harding, Perkins, Meade, Ziebach, Dewey, and Corson Counties. The entire area is in the unglaciated Missouri River section of the Northern Great Plains province, and is at the southern edge of the great lignite-bearing region underlain by the Fort Union formation which includes the western half of North Dakota and a large part of eastern Montana. As the lignite-bearing parts of South Dakota are near the edges of the Cretaceous and Paleocene basins in which the lignite was formed, the beds in the area, when compared to those of North Dakota and Montana, are much more lenticular and relatively thin. The total reserves in the State are thus comparatively small.



Most of the lignite-bearing area is grass-covered plains country, but some parts are deeply dissected into badland topography. Steep-sided, flat-topped buttes are numerous, and the maximum relief is generally about 300 to 600 ft. The most notable of these topographic features are the Cave Hills, the Slim Buttes, and the Short Pine Hills, all in Harding County.

The altitude of the higher land masses ranges from less than 2,000 ft in the eastern part of the lignite-bearing region, not far west of the Missouri River, to more than 3,000 ft in the watershed between the Missouri and Little Missouri drainage systems in the northwestern part of Harding County. Except for the westernmost three or four tiers of townships in the State, which drain into the Little Missouri, the entire lignite-bearing area drains eastward into the Missouri River through the Grand, Moreau, and Cheyenne Rivers. The comparatively steep gradients of these streams and their tributaries, especially in Harding County, are in part responsible for the deep dissection of much of the area.

Northwestern South Dakota has a dry climate; the average yearly rainfall is about 15 in. Long, cold winters alternate with short summers that are hot in the daytime but cool at night. The density of population is only about two to the square mile. Lemmon, close to the North Dakota-South Dakota State line, is the largest town, having a population of less than 3,000; no other town in the area contains as many as 1,000 people. The closest fairly large trading centers are Belle Fourche, southwest of the lignite fields on the edge of the Black Hills, and Mobridge, on the Missouri River about 50 miles east of the Isabel-Firesteel field. (See map, pl. 1.)

Transportation throughout the area is poor. The main line of the Chicago, Milwaukee, St. Paul and Pacific Railroad runs slightly north of west near the State line, crossing into North Dakota near Lemmon. A branch of the same line extends west from Mobridge to Trail City, where it divides; one line continues south and west through Dupree, the county east of Ziebach County, to a terminus at Faith in the northeast corner of Meade County; another branch runs west from Trail City to the lignite fields at Firesteel and Isabel. In the western part of the State, the Chicago and Northwestern Railroad runs through Belle Fourche, 50 miles or more south of the coal-bearing area, and a branch line runs east from Belle Fourche to Newell. The closest rail transportation to the largest lignite deposits in the State, those in Harding and Perkins Counties, is the main line of the Chicago, Milwaukee, St. Paul and Pacific, in North Dakota; this line is nowhere more than 25 miles north of the State line west of Lemmon.

Access to the lignite-bearing region by highway is also difficult. The only paved roads are U S 12 which passes through Lemmon, and a short stretch of State Route 73 south of the same town. The only other Federal highway is U S 85, a good gravel road running north and south through Buffalo in Harding County. Two state highways, both gravelled, cross the area; State Route 73, which runs south from Lemmon, and State Route 8, running

west from Mobridge through Firesteel, Isabel, Bison, and Buffalo, to the Montana State line. Some of the county roads are graded, but most are unimproved. Because of poor rail and highway transportation, coupled with the severe climatic conditions, much of the lignite-bearing portion of South Dakota is completely isolated for a large part of each year.

### Stratigraphy

A stratigraphic column of the rocks exposed in the lignite-bearing part of South Dakota is shown in figure 4. The oldest formation cropping out in the lignite field is the Pierre shale of the Montana group of Late Cretaceous age, the upper 50 ft of which is exposed in the extreme southwest corner of the area. The Pierre shale is composed of drab to black crumbly shale and in some areas contains large amounts of gypsum. It is non-coal-bearing.

Overlying the Pierre shale is the Fox Hills sandstone, which is from 25 to 75 ft thick in the western part of Harding County but which thickens to the east, becoming 300 to 400 ft in northern Meade County. The Fox Hills consists of gray to white sandstone, slightly calcareous in some places, and contains marine Cretaceous fossils. So far as is known it contains no minable coal beds, except possibly in the Stoneville field in Meade County (Searight, 1934) where facies changes make it difficult to distinguish the Fox Hills sandstone from the overlying Hell Creek formation.

The oldest formation containing commercial lignite in South Dakota is the Hell Creek formation, the uppermost unit of the Upper Cretaceous series; in older reports it was considered a part of the "Lance" formation and was thought to be of Eocene age. The Hell Creek is about 425 ft thick and consists of soft limestone and shale, gray sandstone, and thin lenses of lignite. Throughout its outcrop area in South Dakota, the formation is extremely variable in composition. It contains fairly abundant dinosaur remains. These, together with the characteristic dull-gray to purple coloration which caused it to be designated for many years as the "somber beds," make it relatively easy to distinguish from the overlying rock units.

The Ludlow member of the Fort Union formation of Paleocene age, which immediately overlies the Hell Creek formation, is the most prolific lignite-bearing rock unit in South Dakota. The Ludlow is predominantly yellow in color and consists of sandstone and shale, and a considerable number of lignite beds. The member is probably the equivalent of the Lebo shale member and Tullock member of the Fort Union of Montana, which contains several beds of coal. In the western part of Harding County the Ludlow is about 350 ft thick; it thins somewhat toward the east, and in the vicinity of the Harding-Perkins County line it grades laterally into the marine, non-coal-bearing Cannonball formation (Brown, 1948, p. 1271).

The youngest coal-bearing sequence in South Dakota is the Tongue River member of the Fort Union formation, which overlies the Ludlow member in the northern part of the lignite-bearing area.

Age		Formation and group		Thickness (in feet)
Quaternary		Terrace deposits and dunes		?
Tertiary	Miocene (?)	Arikaree(?) sandstone		75-225
	Oligocene	White River formation		45-140
	Paleocene	Fort Union formation	*Tongue River member	425
			*Ludlow member Cannonball formation	0-350
Cretaceous	Late Cretaceous	*Hell Creek formation		425
		Montana group	Fox Hills sandstone	25-400
			Pierre shale	50 exposed

*\*Lignite-bearing unit*

Figure 4. --Generalized section of rocks exposed in the lignite-bearing area of northwestern South Dakota.

There it reaches a maximum thickness of 425 ft and consists of massive fine-grained sandstone, shale, and lignite. Although the Tongue River contains tremendous reserves of lignite and subbituminous coal in North Dakota, Wyoming, and Montana, it contains little commercial lignite in its comparatively small outcrop area in South Dakota.

In the higher parts of Harding and Perkins Counties, especially the Cave Hills, Slim Buttes, and Short Pine Hills, younger rocks overlie the coal-bearing units. The lower of these is the White River formation of Oligocene age (Winchester, 1916), which consists of 45 to 140 ft of light-colored clay and sandstone, containing many lenses of concretionary siliceous material. The sandstone is cross-bedded to a remarkably high degree. The White River lies unconformably on the lower part of the Hell Creek formation in the Short Pine Hills, on the Ludlow member of the Fort Union formation in the Slim Buttes, and on the upper part of the Fort Union in the Cave Hills; the maximum amount of erosion represented by this unconformity is about 1,000 ft or more.

Above the White River formation is 75 to 225 ft of almost massive, fine-grained, calcareous sandstone referred to the Arikaree(?) sandstone of Miocene(?) age (Winchester, 1916). This formation and the White River are the cliff-forming units that hold up most of the high land in the area.

The youngest rocks exposed in northwestern South Dakota are terrace deposits and dunes of Quaternary age, which are of limited areal extent and of small importance to a study of the lignite deposits.

#### Structure

The lignite-bearing area of South Dakota occupies part of a shallow structural basin known as the Lemmon syncline, the center of which is in North Dakota north of the town of Lemmon. Several smaller flexures are superimposed on this major depression, but all are so gentle that they can be recognized only over fairly large areas. This is evidenced by the measured dips of the rocks in the lignite area, which range from 7 to 65 ft per mile in various directions. The Glendive anticline enters the extreme northwestern corner of the State, but there also the rocks are almost flat lying. Faults are almost unknown, and those that have been seen are of small displacement. In summary, it may be said that in northwestern South Dakota structural disturbances are nowhere of sufficient magnitude to affect the attitude or continuity of the lignite beds, or to give rise to serious mining problems.

#### THE SOUTH DAKOTA LIGNITE FIELDS

Although lignite-bearing formations cover a large part of northwestern South Dakota, the known reserves of the State are concentrated largely in Harding County, western Perkins County, and the Isabel-Firesteel field in Dewey and Ziebach Counties. The various mining districts are relatively small in size, reflecting the lenticular nature of the lignite deposits. It should be emphasized, however, that outside of the Isabel-Firesteel district little

exploration for lignite has been carried on, and that future development work may well discover additional fields adapted to commercial mining.

The lignite fields of South Dakota are discussed below, by counties.

#### Harding County

Harding County is in the northwestern corner of South Dakota, and comprises 76 townships, nearly all of which are underlain by lignite-bearing formations. However, only 39 townships are known to contain minable lignite. The original reserves of the county are estimated at 1,700.36 million tons, or 83.6 percent of the South Dakota total of 2,032.91 million tons. For convenience the lignite-bearing area may be divided into three fields: the Little Missouri River field, in the northwest quarter of the county; the Cave Hills field, occupying approximately the northeast quarter; and the Slim Buttes field, in the southeast quarter. The southwest quarter of the county contains no known reserves. (See map, pl. 1.)

Little Missouri River field. --On both sides of the Little Missouri River, which runs north mostly through R. 2 E., thin lignite beds, which are of little importance compared with the deposits to the east, crop out. Reserves of the area are estimated at 21.67 million tons.

Cave Hills field. --The northeastern part of Harding County, extending from the Cave Hills east to the Perkins County line and lying north of the South Fork of the Grand River is here designated for convenience as the Cave Hills field, though the Cave Hills themselves occupy only the western part. The area of about 20 townships in Tps. 20 to 23 N., Rs. 4 to 9 E. is estimated to contain an original reserve of 1,494.32 million tons, including most of the thick and intermediate lignite in the State. Because of the lack of markets and transportation, however, only small mines have been opened.

The minable lignite in the Cave Hills field is in the Ludlow member of the Fort Union formation, which includes the two beds that contain the largest reserves in the State--the Widow Clark and Giannonatti beds. These two lignites appear to be fairly consistent in thickness over considerable distances, though the grass-covered slopes in their outcrop area have prevented accurate mapping and make correlations uncertain at some points.

The lower of the two principal beds is the Widow Clark, which reaches its maximum thickness of 10.7 ft in T. 20 N., R. 9 E. but thins to the north and probably disappears north of the divide between the North and South Forks of the Grand River. It crops out over a large area west of R. 9 E., but at many places is thinner than the 2.5 ft necessary for inclusion in reserve estimates. Analysis 5, table 5, is of a sample from this bed.

The Giannonatti bed, the thickest in South Dakota, and the uppermost lignite in the Cave Hills area, is from 20 to 100 ft above the Widow Clark; the interval increases from west to east. It reaches

its maximum thickness of 13.6 ft in T. 21 N., R. 8 E., where an underground mine was active as late as 1947. At another exposure, in T. 21 N., R. 7 E., the bed is 13.5 ft thick; but from both these exposures the bed thins rapidly. In the first locality it thins to 8.3 ft within half a mile; in the second to 10 ft, and retains this thickness for several miles. In T. 22 N., R. 8 E., the average thickness of the bed is 6.6 ft, the maximum being 12 ft. The Giannonatti bed is correlated with the widespread T-Cross bed of North Dakota, and probably extends northward into that State from T. 23 N., R. 8 E. An analysis of lignite from the Giannonatti bed in sec. 20, T. 21 N., R. 7 E. is given as no. 4 in table 5.

The Widow Clark bed is estimated to underlie approximately 75,850 acres and to contain 551.01 million tons of lignite, of which 450.78 million tons are in the thin category and 100.23 million tons are in the intermediate thickness range. The Giannonatti bed is estimated to underlie approximately 53,850 acres and to contain 511.10 million tons, including 144.87 million tons of thin, 321.53 million tons of intermediate, and 44.70 million tons of thick lignite.

In addition to the Widow Clark and Giannonatti beds several local beds have been named in the area. Among these are the Bon bed, the Hilton bed, and the Bell bed. None of these beds contain large reserves; in fact, more than two-thirds of the reserves of the Cave Hills field are in the Giannonatti and Widow Clark beds, and less than one-third is in all the other beds combined. Analysis 3, table 5, is of lignite from the Hilton bed.

The Giannonatti bed, which is the youngest lignite in the field, lies under shallow cover over a large acreage and offers potential strip-mining possibilities should market and transportation conditions improve to the point where large-scale mining in the area is possible.

Slim Buttes field. --The Slim Buttes are two elongated mesas south of the South Fork of the Grand River in southeastern Harding County. They are capped by the White River formation and the Arikaree(?) sandstone, and extend about 18 miles north and 1 to 6 miles east. Around the base of the Buttes four and possibly more lignite beds of minable thickness crop out, and the area contains a large reserve.

The lowest bed in the Slim Buttes field is an unnamed bed in the Hell Creek formation, which outcrops in T. 16 N., R. 8 E. The bed covers approximately 2,400 acres in this township and averages 3.3 ft in thickness. Much of the area underlain by the bed is suitable for strip-mining operations, but because the area has not been mapped it is impossible to estimate the strippable acreage or tonnage with any degree of accuracy.

The Hell Creek formation in this vicinity contains other lignite beds in addition to the one described above, but none are of minable thickness. However, three minable beds, also unnamed, occur in the Ludlow member of the Fort Union formation in Tps. 16, 17, and 18 N., Rs. 7 and 8 E. The

lowest ranges in thickness from a few inches to 6.0 ft, averaging 3.3 ft in the northern part of the area and 3.9 ft near the southern part. The middle bed is less than a foot to 14.5 ft thick and has been mined at its point of greatest thickness in sec. 36, T. 18 N., R. 7 E. The uppermost bed is less than a foot to 6.0 ft thick; there is great range in thickness within short distances along the outcrop. The correlations of all these beds are somewhat doubtful, as all split at irregular intervals and have stringers or riders that result in the lignite's being too thin to mine at numerous places along the outcrop. The lenticularity of the lignite is shown particularly well at the north end of the Slim Buttes where each of the beds is less than 2.0 ft thick.

Several strip mines have been opened in the past in the Slim Buttes field, but the market is so limited that there has been no production in recent years.

The sides of the Slim Buttes have been subjected to a good deal of slumping and the lower slopes are covered with grass, which may conceal additional beds and larger reserves that might be discovered by drilling. Original reserves of the Slim Buttes field, as estimated on the basis of available information, are 184.97 million tons.

#### Perkins County

Perkins County comprises about 80 townships, 75 of which are underlain by lignite-bearing formations. Of these, 27 townships are known to contain lignite of minable thickness in the Hell Creek formation and the Ludlow and Tongue River members of the Fort Union formation. The lignite in both the Hell Creek and the Ludlow is in thin beds and the aggregate tonnage is small. The outcrop area of these two units is confined largely to the southern part of the county, where the Hell Creek is exposed around the rim of the Lemmon syncline only. The Ludlow member grades into the marine Cannonball formation in the northern and eastern parts of the county. The lignite in the Hell Creek and Ludlow has been mined for local use not only in the areas shown as containing minable coal, but also in townships to the south and east where the beds are less than 2.0 ft thick and therefore excluded from the reserve estimates.

The Tongue River member of the Fort Union formation is exposed over a comparatively small part of Perkins County, north of the South Fork of the Grand River. The member contains several relatively thick beds of lignite, which in a number of places could be stripmined. The most valuable bed is the Lodgepole, which is 5 ft thick or more over most of its outcrop area in Perkins County, and reaches a maximum measured thickness of 9.0 feet. Analysis 12, table 5, shows the characteristics of this lignite. In T. 23 N., R. 13 E., three coal beds, one of which is probably equivalent to the Lodgepole bed, have been found; the upper of these is shown on a published map (Winchester, 1916) and the other two have been prospected privately. The upper bed averages slightly less than 5 ft in thickness, the middle bed is approximately 7 ft, and the lower is about 3 ft thick. The lignite-bearing area covers about 500 acres and is

estimated to contain 5.77 million tons of lignite more than 5.0 ft thick. As it is close to the railroad, it has good possibilities as a strip-mining locality.

The total original reserves of Perkins County are estimated at 186.51 million tons, or 9.2 percent of the total for the State. Of the total, 141.85 million tons are in the thin category and 44.66 million tons in the intermediate thickness category.

#### Meade County

The only known minable lignite in Meade County is in an area of about 255 acres in secs. 3, 4, 9, and 10, T. 9 N., R. 12 E., near the town of Stoneville. The lignite is thought to be in the Hell Creek formation of Late Cretaceous age. The average thickness of the bed is 3.5 ft and the original reserves are estimated at 1.38 million tons. The locality has been the scene of small-scale mining in the recent past, but much of the recovery has been from beds less than 2.5 ft thick.

#### Corson County

On both banks of the Grand River, in Rs. 20, 21, and 22 E., a number of small mines have been opened to obtain lignite for local use. This lignite is in the Hell Creek formation, near the eastern edge of its outcrop. The beds are thin and lenticular; and except for one 5.5-foot measured section, all of the lignite is less than 5.0 ft thick. Also, the beds contain many partings which detract from their value.

No organized prospecting for lignite has been done in Corson County except in the immediate vicinity of a dozen or so small mines. Because of the lenticular nature of the beds and the scattered locations of the mines no attempt has been made to project the lignite beds from one mined area to another. For this reason the original reserves of Corson County are estimated at only 0.56 million tons, all but 0.02 million tons in the thin category.

#### Dewey and Ziebach Counties

The only important lignite-mining field in South Dakota--the Isabel-Firesteel district--is in parts of Tps. 16 and 17 N., R. 21 E. in Ziebach County, and Tps. 16 and 17 N., R. 22 E. and T. 17 N., R. 23 E. in Dewey County. The lignite in this area is not as thick or extensive as that in some other parts of the State, particularly the Cave Hills field in Harding County; but the presence of a branch line of the Chicago, Milwaukee, St. Paul & Pacific Railroad from Trail City to Isabel provides transportation to market and thus makes commercial mining possible.

All recovery in the Isabel-Firesteel district is from the Firesteel bed in the Hell Creek formation, which ranges from a feather edge to 6.0 ft in thickness. The bed has great range in thickness over short distances, a characteristic which is a distinct handicap to mining operations, for it is necessary for the operators to drill on close centers immediately ahead of mining. No long-range drilling program designed to discover new mining areas has been carried on. It is probable, however, that such a program would increase the known tonnage of lignite considerably and might even establish a

connection between the Firesteel bed in the Isabel-Firesteel district with the deposits in Corson County mentioned in the preceding section of this report.

The total estimated reserves of the Isabel-Firesteel district are estimated at 144.10 million tons, of which the Dewey County reserves of 138.10 million tons are classed as measured, the Ziebach County reserves of 6 million tons as indicated.

#### BITUMINOUS COAL IN SOUTH DAKOTA

The only area in South Dakota in which bituminous coal is known to occur in minable quantity is in Fall River County in the southwest corner of the State, south of the Black Hills. Here numerous thin and disconnected beds of high-volatile bituminous coal occur near the base of the Lakota sandstone of the Inyan Kara group of Early Cretaceous age. The Lakota is a massive buff coarse-grained, cross-bedded sandstone, which contains at many localities a well-defined basal conglomerate. It is overlain by a shaly series of beds which grade upward into the Fall River sandstone. The coal in the Lakota is, in South Dakota, too thin to mine at all known localities except one in T. 7 S., R. 2 E., and another in T. 9 S., R. 3 E., where it reaches a thickness of 4.5 ft but thins to a knife edge within about 300 ft in both directions. The original reserves of the coal are estimated at about 6,800 tons in T. 7 S., R. 2 E., and 4,100 tons in T. 9 S., R. 3 E., or a total of 10,900 tons. These small reserves of bituminous coal are not included in the tables of lignite reserves.

The bituminous coal in Fall River County has been mined to a small extent. The last-reported mine was operated in 1935. It is still used by ranchers who mine it for their own use; but the coal is so lenticular, usually lensing out to a knife edge within 500 ft from the thickest part of the outcrop, that a minable deposit is uncovered only through considerable luck. On the other hand, there are probably pockets of coal in the Lakota sandstone across the State; it has been noted as far east as Mitchell, S. Dak., and at a point just west of Sioux City, Iowa. None of these occurrences are of commercial importance. In the same formation, in the area north of the Black Hills, bituminous coal is known to be present, but has never been prospected. Farther west, in the Newcastle district of Wyoming, coal at the same horizon reaches a thickness of 9 ft.

#### PRODUCTION OF LIGNITE IN SOUTH DAKOTA

The first lignite mining in South Dakota was by ranchers and settlers who dug the coal for their own use. The first geologist to describe the lignite-bearing area was N. H. Winchell, who accompanied Capt. William Ludlow on a military expedition to the Black Hills in the summer of 1874; his report was included in Capt. Ludlow's Journal (Winchell, 1875, pp. 1131-1172). In 1893 J. E. Todd, State Geologist of South Dakota, made a reconnaissance trip through the lignite-bearing area and published a description (Todd, 1898). Since that time the region has been the subject of a number of publications describing counties and smaller areas; most

of these publications are listed in the selected bibliography.

No reliable figures covering the mining of lignite in South Dakota prior to 1913, the first year in which production was reported, are available; but it may be assumed that the amount mined before that year was small, and mostly for local use. From 1913 through 1950 reported production for the State is 989,361 tons. The peak years were 1933, with almost 60,000 tons mined, and 1941, when slightly more than 70,000 tons were mined. A study of the chart (fig. 3) shows that the South Dakota production has a tendency to decrease in prosperous times, when coal of higher rank is imported, and to increase during periods of depression.

#### Mining methods

As the production figures show, nearly all of the lignite mined in South Dakota comes from small local operations; the mines in the Isabel-Firesteel area are the only exceptions. Because of the large number of places where fair-sized blocks of coal lie close to the surface, and because of the unfavorable roof and floor conditions and the scarcity of timber for underground mining, nearly all coal mined in the State is recovered by stripping operations. The comparatively few underground mines are usually without definite mining plans. The only large operations in the State, near Isabel and Firesteel, are strip mines; overburden is removed by large shovels and the coal is loaded by smaller shovels into trucks and hauled to the tiple or railroad.

#### Strip-mining possibilities in South Dakota

Because of conditions mentioned in the preceding section, it is probable that all, or nearly all, lignite mining in South Dakota in the near future will be by strip-mining methods. The conditions which make strip mining profitable vary greatly from place to place and it is impossible to apply rules for all areas. At the present time, in the Midwestern States, operators of strip mines in bituminous coal can afford to move 20 ft or more of overburden for each foot of coal recovered, and this stripping ratio of 20:1 is generally accepted as a rough maximum for that area (Koenig, 1950, p. 28). In the Northern Great Plains region, of which South Dakota is a part, the coal is of lower rank than in the Midwest, and because it brings a lower price the profitable stripping ratio is accordingly less; the figure of 10:1 is widely considered as the maximum. However, the subbituminous coal and lignite of the Northern Great Plains region is so thick and so near the surface at many places that it is possible to mine tremendous tonnages at stripping ratios of 4:1 and even less. The determining factor in deciding whether to strip-mine a given deposit is not the stripping ratio, but the amount of overburden that can be moved economically with available equipment. The present maximum, using the heaviest equipment in service, is about 125 ft; and 60 to 65 ft can be handled by many of the shovels and draglines now in use. Because of the relative thinness of the South Dakota lignite--only the Giannonatti bed is as much as 10 ft thick over a sizeable area and most of the lignite is less than 5 ft thick--it is doubtful if it will be considered

feasible, at least in the immediate future, to move more than 60 ft of cover.

Because of the lack of topographic maps and of closely-spaced points of information on the coal-bearing areas, it is impossible to outline strippable areas on the bed maps or to estimate strippable tonnages in any area. However, in the discussions probable or possible strippable areas have been mentioned in describing the different fields. The only part of the State in which commercial strip-mining is now being done is the Isabel-Firesteel field. As previously mentioned, this is due to the presence of rail transportation, rather than to the thickness of the lignite beds there. The largest potential stripping area in the State is that underlain by the Giannonatti bed in the Cave Hills field. This bed contains more than one-fourth of the estimated original reserves of the State, and much of it is known to be under fairly thin cover. The closest railroad is the main line of the Chicago, Milwaukee, St. Paul and Pacific Railroad, which runs not far north of the State line in North Dakota and at most places within 25 miles or less of the lignite beds. Another large area is in T. 16 N., R. 8 E., in the Slim Buttes field, where an unnamed bed in the Hell Creek formation averages 3.3 ft in thickness over 2,400 acres, much of which could be strip-mined profitably. The only area except the Isabel-Firesteel field that offers attractive strip-mining possibilities and is yet reasonably close to a railroad is a butte in T. 23 N., R. 13 E.; here the coal is from 3.6 to 7.0 ft thick and the overburden is thin. The principal drawback to a successful operation here is the limited reserves, amounting to only about 7.0 million tons.

No strip mining should be attempted in any of the fields mentioned above until drilling and surface prospecting have outlined the areas which can be mined economically; until this is done, and until better maps than those now available are made, it will be impossible to estimate the tonnage of strippable coal in South Dakota, or to locate all the areas favorable for strip mining.

#### THE FUTURE OF LIGNITE MINING IN SOUTH DAKOTA

The reported production of lignite in South Dakota in 1948 was 29,094 tons (Minerals Yearbook, 1949). Department of Commerce figures on car-loadings terminating in the State show that 1,212,669 tons of coal were imported by rail from other states during the same year. This means that South Dakota produced only 2.4 percent of the coal it consumed. Generally speaking, the coal used in the north-central and northeastern parts of the State comes largely from North Dakota, and that used in the southern and southeastern sections from Illinois. The southwestern part of the State, including the cement plant and smelters of the Black Hills, is supplied mainly from the Gillette field in north-eastern Wyoming.

During the years 1947-50, only five mines in South Dakota sold lignite commercially--these were the mines which produced more than 1,000 tons per year. Undoubtedly there are many mines in the State which produce for local use, but which are

not included in the production figures. Only two of the larger mines were in operation in the spring of 1951; the Dewey County Coal Co. mine in secs. 17, 18, and 21, T. 17 N., R. 23 E., which strips the Firesteel bed at a locality where it is 4.5 ft thick, and the Edwin Keller & Sons strip mine in sec. 36, T. 19 N., R. 21 E., in Corson County, which mines 4.0 to 4.5 ft of lignite. The Joe Pinter mine in the SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 35, T. 21 N., R. 8 E., in the Cave Hills field in Harding County was last operated in the winter of 1946-47. This was an underground mine in the Giannonatti bed, which reached a thickness of 13.6 ft in the mine. Two other mines--that of Jake Miller, of Isabel in Dewey County, and that of Edwin Harris, of Strool in Perkins County, have been active during the period 1947-50.

As the South Dakota lignite fields are on the edge of the region underlain by the Fort Union formation with its tremendous deposits of thick lignite and subbituminous coal, mining in the State has been, and probably will continue to be, largely marginal until and unless the transportation system, either rail or highway, is greatly improved. This is especially true of the eastern half of Harding County, where the coal is thick enough and of sufficient quantity to support a fair-sized mining district, and where a potential market is available in the Black Hills to the south. The Cave Hills area could also supply fuel for present and projected power plants in southwestern North Dakota and northwestern South Dakota; and it is at least possible that the present trend toward the use of oil for that purpose may be arrested, particularly in view of the research now being carried on for the better utilization of lignite as boiler fuel.

Like all coal in the region underlain by the Fort Union formation, the South Dakota lignite is well suited for the production of synthetic liquid fuels, although the comparative thinness of the beds in most parts of the State is a disadvantage.

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