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COAL GEOLOGY AND RESOURCE CALCULATIONS OF THE SOUTH BELFIELD AREA, BILLINGS AND STARK COUNTIES, NORTH DAKOTA

By

Arthur C. Banet, Jr.

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[Plates in pocket]

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Conversion Table

To convert English units	Multiply by	To obtain metric units
Inches	2.54	Centimeters
Feet	.3048	Meters
$Miles^2$	2.589	$Kilometers^2$
Ton (short)	.9072	Metric tons

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ABSTRACT

Coal-exploration drilling shows that there are eight major lignite beds in the south Belfield area. These are the Hansen, Harmon, Nomad, Garner Creek, Coal Bank Creek-Meyer, HT Butte, Fryburg, and Heart River, in ascending stratigraphic order. Coal resource calculations are provided for all beds in the area by township; resource calculations for the Heart River and Fryburg beds are divided into overburden categories of 0-20 ft, 20-150 ft, and greater than 150 ft. Total resources amount to more than 6 billion tons of coal. Shallow uraniferous coal is also considered as a local resource.

INTRODUCTION

Coal of lignite grade and rank is prevalent in much of southwest North Dakota. In the south Belfield area, Tps. 137 and 138 N., Rs. 99 and 100 W., Billings and Stark Counties, southeast of Theodore Roosevelt National Memorial Park (fig. 1), there are eight major coal beds greater than 5 ft thick. These coals are, in ascending stratigraphic order, the Hansen, Harmon, Nomad, Garner Creek, Coal Bank Creek-Meyer, HT Butte, Fryburg, and Heart River (table 1). All the coals are in either the Tongue River or Sentinel Butte Members of the Fort Union Formation (Paleocene). Coal resources were calculated in response to current program objectives of the U.S. Geological Survey.

Data used for coal-bed identification, correlation, and resource calculations are a collection of oil-well gamma-ray logs, North Dakota State Water Well Commission (NDSWC) lithologic logs, and geophysical logs (gamma-ray, density, spontaneous potential, and resistivity) from the U.S. Geological

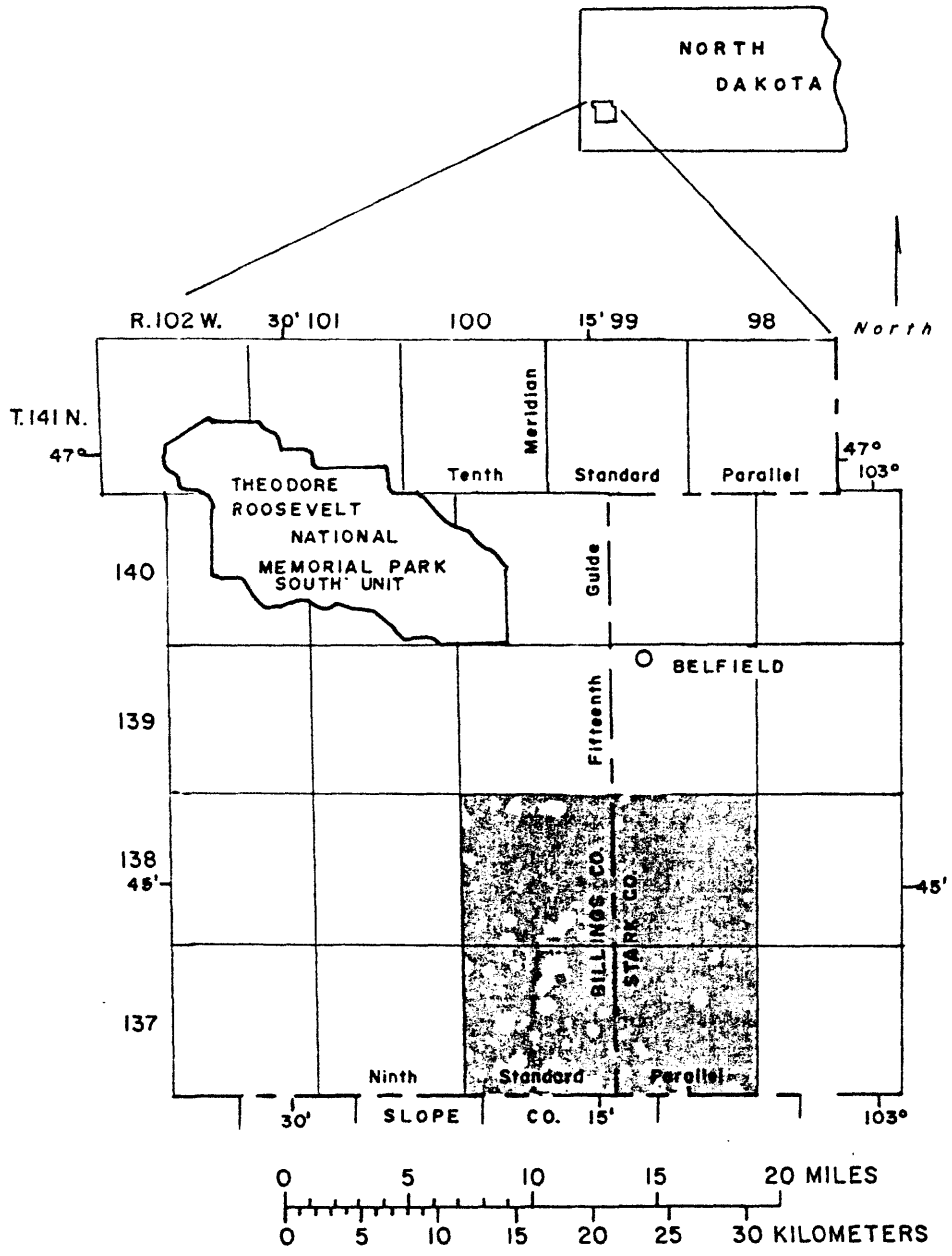

Figure 1.--Index map of the south Belfield area. Study area is shaded.

Table 1.--Stratigraphic position and names of coal beds in the south Belfield area Billings and Stark Counties, North Dakota

[---, not reported]

		This report	Owen 1979	Lewis 1979	Brant 1953	Hares 1928	Leonard and others 1925	Wilder and Wood 1902
FORT UNION FORMATION	Sentinel Butte Member	Heart River	Heart River	---	---	---	Heart River	---
		Fryburg	Fryburg	Fryburg	---	---	Fryburg	---
	Tongue River Member	HT Butte	HT Butte	HT Butte	---	HT Butte	---	---
		Coal Bank Creek-Meyer	Coal Bank Creek	Meyer	H	Meyer	Coal Bank Creek	Cited (p. 161)
		Garner Creek	Garner Creek	Garner Creek	E	Garner Creek	---	---
		Nomad	Nomad	local	---	---	---	---
		Harmon	Harmon	Harmon	D	Harmon	---	---
		Hansen	Hansen	Hansen	C	Hansen	Haynes	---

Survey-North Dakota Geological Survey (USGS-NDGS) coal-evaluation project. Surface geology and stratigraphic contacts are from Royse (1967, 1970), Bluemle (1975), and Hickey (1976).

Previous Work

Coal-bed description and measurement studies in this part of the Williston Basin date back to the early part of the twentieth century (Wilder and Wood, 1902; Clapp and Babcock, 1906; Leonard, Babcock, and Dove, 1925); more detailed mapping followed (Brant, 1953; Caldwell, 1954) as topographic control improved. The most recent reports (Menge, 1977; Rehbein, 1978; Owen, 1979; and Lewis, 1979) incorporate coal-evaluation geophysical logs and outcrop measurements. Parts of the south Belfield area are overlapped in reports by Menge (1977) from the north, Owen (1979) from the southeast, and Lewis (1979) from the west. However, coverage of the area in those reports is poor due to an insufficient amount of data.

Physiography

A north-trending divide located in the western part of the area (pl. 1) separates the south Belfield area into two distinct provinces. In the east, gently rolling hills and prairie lands are drained by the northeast-flowing South Branch of the Heart River and several northeast- or east-flowing creeks. Most of the land is in grain crops or cattle production. West of the divide the terrain is sharply dissected by westerly flowing seasonal streams. This part of the area is mainly badlands or shortgrass country used only for cattle grazing.

STRATIGRAPHY

Fort Union Formation

The coal-bearing strata of the Williston Basin of North Dakota are synonomous with the Fort Union Formation (Paleocene). All the coals studied in this report are in either the Tongue River or Sentinel Butte Members of

the Fort Union. Coals in the Ludlow Member of the Fort Union were not considered. The Fort Union Formation is conformably overlain by the Golden Valley Formation (Paleocene-Eocene) along the east border and in scattered outliers (pl. 3).

Approximately 500-600 ft of the Tongue River Member (Rehbein, 1978) conformably overlies the Ludlow, except in small isolated areas (Hares, 1928, p. 37; Carlson, 1969). The Tongue River consists of a nonmarine, fluvial-lacustrine sequence of interbedded siltstone, claystone, coal, and sandstone. The sandstones are mostly fine grained or very fine grained, usually grading into siltstone (0.30-0.03 mm diameter). Gamma-ray and density logs of the Tongue River distinctly show the coals and clastic sediments (pls. 2A, 2B). The "sands" are mainly block-shaped, indicative of an even texture, or bell-shaped, indicative of a fining upward sequence (Fisher and others, 1969; Kaiser, 1974). These sequences either grade upward into point-bar deposits or are overlain by the "clays" and "silts" of overbank deposits (Rehbein, 1978). Crevasse-splay sequences that coarsen upward are noted but not common (pls. 2A, 2B). Lignite interbedded with overbank deposits of fluvial-lacustrine sediments formed in very large swamps adjacent to the channels. Most Tongue River coals show these depositional characteristics, especially the broad areal extent. Royse (1967, 1970) and Jacob (1973), in their sedimentologic studies, reached similar conclusions for the depositional environment of the Tongue River.

The Sentinel Butte Member conformably overlies the Tongue River strata (Royse, 1970). There are only minor differences in the gamma-ray and density log patterns and lithologic descriptions between the two members, which suggests a very similar environment of deposition (Royse, 1967, 1970) (pls. 2A, 2B). Because of distinct lateral changes in lithology, and poor surface exposures, it is often difficult to determine exact stratigraphic

positions in the field or on logs. Royse (1967, 1970) extensively studied the problem and established three criteria to define the Tongue River-Sentinel Butte contact: (1) HT Butte coal bed; (2) marked color change; and (3) basal sandy unit.

The top of the HT Butte coal bed, at base of the Sentinel Butte where the bed is present, is suggested as the contact. Royse (1967, 1970) found the HT Butte coal bed, carbonaceous zone, or lignitic shale at several exposures and noted thicknesses varying from inches to several tens of feet. Problems associated with using the HT Butte bed as a contact are slumping of overlying sediments, erosion, nondeposition of the coal, and a plethora of names (Law, 1977, fig. 1) attached to this coal at various localities.

The color change at the contact is due to weathering. The claystone, siltstone, and sandstone of the Sentinel Butte generally weather to dark brown or gray, whereas the Tongue River lithologies generally weather to tan or buff color. Drill-hole cuttings of the two members, however, show no color difference. Laboratory studies indicate that there is a slightly larger grain size and greater $CaCO_3$ content in the Sentinel Butte than the Tongue River (Royse, 1967, 1970).

The third criterion is a persistent basal sand unit that ranges in thickness from several feet to more than 100 feet. Plates 2A and 2B show a blocky shaped channel sand, usually above the HT Butte zone, and in some places a channel sand below the coal.

Golden Valley Formation

The Bear Den Member (Clarkforkian age) of the Golden Valley Formation (transitional Paleocene-Eocene) conformably overlies the Sentinel Butte (Hickey, 1976) along the eastern boundary of the area (pl. 3). USGS drill-hole lithologies show approximately 40 ft of yellow-tan or pale-yellow-green

claystone, siltstone, and mudstone. These sediments are unique because their light color is easily recognized in drill cuttings. The claystones are kaolinitic, and the siltstones are commonly micaceous. No Golden Valley coals were found in the area.

White River Group

The basal Chadron Formation of the White River Group (Oligocene) unconformably overlies the tilted and beveled edges of the Golden Valley and older formations (Denson and Gill, 1965, p. 4)(pl. 3). The lower part of the Chadron consists of arkose and thin conglomerate lenses overlain by dark-gray bentonite, mildly radioactive tuffaceous sandstone, claystone, and siltstone. Leaching of uranium from the tuffaceous units across the angular unconformity is proposed by Denson and Gill (1956, 1965) and N. M. Denson (oral commun., 1980) as a mechanism for uranium mineralization of the Fort Union coals.

STRUCTURE

The south Belfield area is located in the southern part of the Williston Basin, where the Fort Union and older beds generally dip at 1° NE or less (pl. 3). Local variations in the regional structure pattern are common.

COAL

Eight coal beds--the Hansen, Harmon, Nomad, Garner Creek, Coal Bank Creek-Meyer, HT Butte, Fryburg, and Heart River--were studied and evaluated for coal resources (table 2). The overlying Lehigh bed, found in only two drill holes (USGS 128 and 129, pl. 2B), and the local beds are not evaluated because they are not at least 5 ft thick. Correlation sections, based on geophysical logs, show the changes in coal-bed thickness and lateral variations in lithologies, and are the basis for the interpretation of depositional environments (pls. 2A, 2B). Commonly, the beds near the surface have been weathered (slack). Log response on these coals is poor, and drill cuttings do not provide an accurate thickness; therefore, the coal horizon is shown as slack (pl. 4).

Table 2.--Coal resources for all major coal beds of the south Belfield area, Billings and Stark Counties, North Dakota

[Calculations based on 1,750 tons/acre-ft x thickness x acres; resources given in thousands of short tons]

Coal bed name	T. 137 N., R. 99 W.	T. 138 N., R. 99 W.	T. 137 N., R. 100 W.	T. 138 N., R. 100 W.	Totals
Heart River	116,555	130,355	89,877	51,960	388,747
Fryburg	328,041	367,698	321,075	429,417	1,446,231
HT Butte	155,304	2,134	134,381	60,619	352,438
Coal Bank Creek-Meyer	303,184	389,878	273,756	176,269	1,143,087
Garner Creek	418,080	99,295	373,340	82,731	973,446
Nomad	155,361	246,088	10,014	16,002	427,465
Harmon	446,799	46,064	421,061	54,100	968,024
Hansen	242,464	---	376,940	7,788	627,192
Totals	2,165,788	1,281,512	2,000,444	878,886	6,326,630

At present, there are no chemical and physical analyses available for any of the coals in the south Belfield area. Analyses of the coals in adjacent areas are provided in Menge (1977), Owen (1979), and Lewis (1979). The coals are discussed from shallowest to deepest bed because the data base is more complete for the shallow beds.

The Heart River bed, 0-8 ft thick in the Sentinel Butte Member, is the highest recoverable coal bed in the stratigraphic section; it is overlain by approximately 25-160 ft of overburden. Where overburden is thin, the coal is usually weathered, or slack. Plate 4 shows the Heart River bed as two elongate pods with sharp boundaries of channel sands.

The Fryburg bed (pl. 5), 0-16 ft thick, is the principal recoverable coal resource in the area. It is 32-62 ft below the Heart River and is covered by less than 150 ft of overburden throughout most of the area. The coal bed is thickest to the north and has no partings except at one data point in the southwest.

Coal-resource calculations for all beds in the area are listed by township in table 2. Table 3 shows resource calculations for only the Heart River and Fryburg beds and are listed by section, township, and range with overburden categories of 0-20 ft, 20-150 ft, and greater than 150 ft.

The HT Butte bed (pl. 6), 0-8.5 ft thick, is 60-135 ft below the Fryburg and is considered by Royse (1967, 1970) to be the contact between the Sentinel Butte and Tongue River Members. Plate 6 shows the HT Butte to be elongate, pinching out towards the east and west. Plates 2A and 2B show that the HT Butte is generally in a sandy part of the section, indicating the existence of Royse's (1967) basal Sentinel Butte sand unit. Because the HT Butte bed is thin and 60-135 ft below the Fryburg, only total coal resources are calculated (table 2).

Table 3.--Coal resources for the Heart River and Fryburg beds

[Calculations based on 1,750 tons/acre-ft x thickness x acres (excluding coal less than 5-ft thick) in categories of 0-20 ft, 20-150 ft, and greater than 150 ft overburden; resources in thousands of short tons]

Location	Overburden					
	Heart River			Fryburg		
	0-20	20-150	>150	0-20	20-150	>150
T. 137 N., R. 99 W.,						
Sec. 1	--	--	--	--	6,160	--
2	--	--	--	--	6,720	--
3	--	--	--	--	7,719	--
4	--	971	--	--	9,177	--
5	--	7,280	--	--	10,640	--
6	--	7,280	--	--	--	--
7	--	1,559	--	--	10,976	--
8	--	2,150	--	--	9,733	--
9	--	296	--	--	9,158	253
10	--	95	--	--	8,736	--
11	--	3,185	--	--	7,840	--
12	--	1,943	--	--	6,939	--
13	--	5,292	693	--	7,840	1,050
14	--	6,405	341	--	8,447	386
15	--	1,827	--	--	8,848	--
16	--	--	--	--	7,438	2,205
17	--	--	--	--	3,465	6,615
18	--	--	--	--	10,075	565
19	--	--	--	--	9,497	583
20	--	1,435	--	--	3,355	6,725
21	--	5,005	44	--	3,824	6,458
22	--	7,257	--	--	7,398	3,071
23	--	7,280	--	--	9,975	630
24	--	7,840	--	--	5,775	5,536
25	--	8,960	--	--	7,788	3,413
26	--	8,736	--	--	11,760	--
27	--	8,400	--	--	11,704	360
28	--	6,358	--	--	11,454	788
29	--	4,985	--	--	9,329	613
30	--	4,195	--	--	8,736	--
31	--	--	--	--	6,328	--
32	--	--	--	--	6,825	--
33	--	44	--	--	8,778	216
34	--	1,921	--	--	8,540	473
35	--	2,772	--	--	8,736	--
36	--	2,006	--	--	8,111	277
Total	--	115,477	1,078	--	287,824	40,217

Table 3.--Coal resources for the Heart River and Fryburg beds - continued

Location	Overburden					
	Heart River			Fryburg		
	0-20	20-150	>150	0-20	20-150	>150
T. 138 N., R. 99 W.						
Sec. 1	--	--	--	--	15,568	--
2	--	--	--	--	16,072	--
3	--	1,499	--	--	15,904	--
4	--	5,824	--	--	15,568	
5	--	4,568	--	--	15,568	--
6	--	347	--	--	15,049	21
7	--	3,969	--	--	12,282	39
8	--	6,272	--	--	13,216	--
9	--	6,384	--	--	13,328	--
10	--	2,748	--	--	14,000	--
11	--	--	--	--	14,560	--
12	--	--	--	--	14,630	--
13	--	--	--	--	14,000	--
14	--	--	--	--	13,328	--
15	--	3,339	--	--	13,020	420
16	--	6,720	--	--	10,724	364
17	--	6,944	--	--	11,411	366
18	--	6,832	--	--	12,089	231
19	--	6,944	--	--	11,760	--
20	--	6,944	--	--	9,940	--
21	--	6,944	--	--	7,952	--
22	--	3,138	--	--	5,862	--
23	--	--	--	--	5,365	--
24	--	--	--	--	8,148	--
25	--	--	--	--	--	--
26	--	--	--	--	--	--
27	--	2,310	--	--	1,983	--
28	--	6,944	--	--	7,560	--
29	--	7,056	--	--	8,736	--
30	--	7,168	--	--	11,760	--
31	--	7,392	--	--	11,760	--
32	--	7,392	--	--	8,960	--
33	--	7,168	--	--	7,840	--
34	--	5,509	--	--	6,562	--
35	--	--	--	--	1,752	--
36	--	--	--	--	--	--
Total	--	130,355	--	--	366,257	1,441

Table 3.--Coal resources for the Heart River and Fryburg beds - continued

Location	Overburden					
	Heart River			Fryburg		
	0-20	20-150	>150	0-20	20-150	>150
T. 137 N., R. 100 W.						
Sec. 1	--	6,384	--	--	11,760	--
2	--	4,793	--	--	11,760	--
3	--	3,274	--	--	10,786	918
4	--	992	--	--	1,488	8,547
5	--	--	--	--	2,833	7,245
6	--	--	--	--	4,537	4,983
7	--	--	--	47	7,812	2,097
8	473	2,785	--	--	1,380	9,553
9	--	6,160	--	--	303	11,448
10	--	6,048	--	--	2,609	9,151
11	182	3,476	--	--	10,547	1,213
12	89	2,050	--	--	--	11,760
13	--	--	--	--	11,424	--
14	--	--	--	--	11,246	496
15	--	1,629	--	--	10,198	1,562
16	95	5,782	--	--	963	11,358
17	924	3,948	--	643	7,718	2,481
18	312	452	--	--	--	--
19	--	--	--	1,470	1,278	--
20	473	483	--	--	2,000	5,121
21	294	5,597	--	--	3,914	7,846
22	--	577	--	--	9,328	1,835
23	--	--	--	110	11,148	--
24	--	--	--	--	2,520	--
25	--	--	--	--	9,461	63
26	--	3,707	--	--	6,899	3,182
27	--	5,208	945	--	316	10,324
28	159	4,789	--	496	4,673	5,093
29	--	--	--	1,544	2,113	--
30	--	--	--	135	--	--
31	--	--	--	--	--	--
32	--	--	--	1,654	276	--
33	578	1,760	95	1,873	5,665	554
34	39	3,507	2,730	--	2,261	8,379
35	--	6,668	48	--	4,254	5,576
36	337	2,035	--	--	8,848	--
Total	3,955	82,104	3,818	7,972	182,318	130,785

Table 3.--Coal resources for the Heart River and Fryburg beds - continued

Location	Overburden					
	Heart River			Fryburg		
	0-20	20-150	>150	0-20	20-150	>150
T. 138 N., R. 100 W.						
Sec. 1	--	--	--	--	15,568	--
2	--	--	--	--	15,736	--
3	--	--	--	--	16,240	--
4	--	--	--	--	13,398	2,842
5	--	--	--	2,106	7,714	6,344
6	--	--	--	2,309	1,167	--
7	--	--	--	3,378	5,288	--
8	--	--	--	3,595	8,509	887
9	--	--	--	--	6,024	1,502
10	--	--	--	--	14,261	66
11	--	--	--	--	14,224	--
12	--	--	--	--	13,636	--
13	--	2,345	--	--	12,880	--
14	--	--	--	--	12,880	--
15	--	--	--	--	13,043	64
16	--	--	--	--	12,390	1,068
17	--	--	--	1,388	11,235	819
18	--	--	--	1,536	10,260	946
19	--	--	--	1,559	9,548	289
20	--	--	--	443	10,434	1,444
21	--	--	--	481	11,839	--
22	--	--	--	--	12,040	--
23	--	1,785	--	--	11,956	--
24	--	6,597	--	--	12,180	--
25	--	6,944	--	--	11,760	--
26	--	6,213	--	--	12,320	--
27	--	7,785	--	--	11,760	--
28	--	--	--	--	11,536	--
29	--	--	--	--	10,976	--
30	--	--	--	748	8,146	1,230
31	--	--	--	166	7,970	1,845
32	--	--	--	--	9,759	881
33	--	453	--	--	9,204	1,520
34	--	5,838	--	--	--	--
35	--	6,944	--	--	11,760	--
36	--	7,056	--	--	12,320	--
Total	--	51,960	--	17,709	389,961	21,747

The Coal Bank Creek-Meyer bed (pl. 7), 4-12 ft thick and 3-35.5 ft below the HT Butte bed, is continuous over the entire area. The hyphenated name is used here because the coal beds originally described by Leonard and others (1925) and Hares (1928) as the Coal Bank Creek and Meyer beds, respectively, are now correlated as the same bed (Owen, 1979)(table 1). Menge (1977) described a lower bench of the HT Butte bed, HT Butte 2, which may be the Coal Bank Creek-Meyer bed.

Correlation problems are common to Fort Union coals. Plate 2B shows such a situation. The HT Butte, an important marker bed, pinches out to the northeast and a local coal below the Coal Bank Creek-Meyer comes in with approximately the same interburden above (∿25 ft) and below (∿20 ft) the Coal Bank Creek-Meyer. Poor logs or widely spaced data would show this similar coal and rock interval, resulting in a miscorrelation that would falsely indicate the HT Butte bed is continuous in this area.

The Garner Creek bed (pl. 8), 0-13 ft thick, is 57.5-165 ft below the Coal Bank Creek-Meyer bed. Both coal thickness and interburden increase southward. Logs (pls. 2A, 2B) show that most of the interval above is an even-grained sandstone or siltstone, except in the northwest where a thinner sequence of claystone and mudstone overbank sediments replace the sandstone. The lithology of the interval beneath is also quite variable (Owen, 1979, p. 7), consisting mainly of overbank deposits in this area.

The Nomad bed (pl. 9), 0-9 ft thick and 23-167 ft below the Garner Creek bed, thickens toward the east and southeast. Owen (1979) named the bed in the New England-Mott area.

The Harmon bed is 3-17 ft thick in the area (pl. 10), thinning northward. Recent authors (Rehbein, 1978; Owen, 1979; Lewis, 1979) have tentatively correlated this bed over an area of approximately 12,000 mi^2. Resource calculations (Rehbein, 1978) indicate that the Harmon bed is one of the largest coal deposits in North Dakota

Overburden on the Harmon bed is generally greater than 500 ft in most of the south Belfield area, except in the southwest where it crops out in the badlands. Interburden between the Harmon and Nomad is variable (Owen, 1979, pl. 1). The interburden between the Harmon and Fryburg beds is approximately 500 ft in the area (Hal Owen, oral commun., 1979), despite thickness changes of the various lithologies (pls. 2A, 2B) and coal beds in this interval.

The Hansen bed, 4-17 ft thick (pl. 11), is 15-82 ft below the Harmon. Locally, the interburden varies greatly, thickening northward. Regionally, the interburden ranges in thickness from a few feet to more than a hundred feet (Hal Owen and R. C. Lewis, oral commun., 1979). The Hansen is the basal Tongue River coal in southwestern North Dakota. Because it is so low in the section, only oil wells and deep coal-exploration drill holes penetrate it. Despite a limited data base, coal resource calculations are listed in table 2 for the southern part of the south Belfield area where data are sufficient.

URANIUM

In addition to coal, uranium also is an economically minable resource in this area. Denson and Gill (1965) reported uranium concentrations in the coal ranging from 0.005 to 0.02 percent (average 0.008 percent). Uranium concentrations in the lignite ash range from 0.05 to 0.1 percent. Mitchell (1965) reported on methods of extracting uranium from lignite, on mining near Belfield during the 1960's, and on potential uranium reserves of approximately 1 million tons.

Plate 2B (section B-B') shows gamma-ray log response from uranium-bearing coal (holes 128 and 129). Maximum deflection is approximately 325 counts (API units), which is approximately three times background. Lithologic logs show that the uraniferous coals are severely weathered as are most shallow coals.

SUMMARY

There are eight major coal horizons in the south Belfield area, Tps. 99 and 100 W., Rs. 137 and 138 N. Total coal resources for all coals in the area are 6,326,630,000 tons.

Bed name	Thousands of short tons
Heart River	388,747
Fryburg	1,446,231
HT Butte	352,438
Coal Bank Creek-Meyer	1,143,087
Garner Creek	973,446
Nomad	427,465
Harmon	968,024
Hansen	627,192

The Lehigh bed is not thick enough in this area to be considered as a coal resource, but it has been used as an economical uranium resource.

REFERENCES CITED

Bluemle, J. P., 1975, Guide to the geology of southwestern North Dakota: North Dakota Geological Survey and North Dakota Department of Public Instruction Educational Series 9, 37 p.

Brant, R. A., 1953, Lignite resources of North Dakota: U.S. Geological Survey Circular 226, 78 p.

Caldwell, J. W., 1954, Surface structure of western Stark County and adjacent areas of North Dakota: North Dakota Geological Survey Report of Investigations no. 14, 2 p.

Carlson, C. G., 1969, Bedrock geologic map of North Dakota: North Dakota Geological Survey Miscellaneous Map 10, scale 1:1,000,000.

Clapp, C. H., and Babcock, E. J., 1906, Economic geology of North Dakota clays: North Dakota Geological Survey Biennial Report 4, p. 95-189.

Denson, N. M., and Gill, J. R., 1956, Uranium-bearing lignite and its relation to volcanic tuffs in eastern Montana and North and South Dakota, in Page, L. R., and others, compilers, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United National International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U.S. Geological Survey Professional Paper 300, p. 413-418.

_____ 1965, Uranium-bearing lignite and carbonaceous shale in the southwestern part of the Williston basin--A regional study with a section on Heavy minerals in Cretaceous and Tertiary rocks associated with uranium occurrences, by W. A. Chisholm: U.S. Geological Survey Professional Paper 463, 75 p.

Fisher, W. L., Brown, L. F., Jr., Scott, A. J., and McGowen, J. H. (leaders), 1969, Delta systems in the exploration of oil and gas--A research colloquium, Austin, Texas, 1969, Syllabus [No. 1]: University of Texas at Austin, Bureau of Economic Geology, 78 p.

Hares, C. J., 1928, Geology and lignite resources of the Marmarth field, southwestern North Dakota: U.S. Geological Survey Bulletin 775, 110 p.

Hickey, L. J., 1976, Stratigraphy and paleobotany of the Golden Valley Formations (early Tertiary) of western North Dakota: Geological Society of America Memoir 156, 183 p.

Jacob, A. F., 1973, Depositional environments of the Paleocene Tongue River Formation, western North Dakota: American Association of Petroleum Geologists Bulletin, v. 57, p. 1038-1052.

Kaiser, W. R., 1974, Texas lignite: near-surface and deep basin resources: University of Texas, Austin, Bureau of Economic Geology Report of Investigations 79, 70 p.

Law, Ronald, 1977, Preliminary report on the geology of the near-surface coal beds in the Knife River area, North Dakota: U.S. Geological Survey Open-File Report 77-481, 12 p.

Leonard, A. G., Babcock, E. J., and Dove, C. P., 1925, The lignite deposits of North Dakota: North Dakota Geological Survey Bulletin 4, 240 p.

Lewis, R. C., 1979, Coal geology of the Bowman-Gascoyne area, Adams, Billings, Bowman, Golden Valley, and Slope Counties, North Dakota: U.S. Geological Survey Open-File Report 79-1698, 35 p.

Menge, M. L., 1977, Preliminary report on the coal resources of the Dickinson area, Billings, Dunn, and Stark Counties, North Dakota: U.S. Geological Survey Open-File Report 77-482, 11 p.

Mitchell, R. J., 1965, Uranium-bearing lignite--North Dakota's newest industry: Metal Mining and Processing, v. 2, no. 3, p. 16-23.

Owen, Hal, 1979, Coal geology of the New England-Mott area: Billings, Stark, Slope, Hettinger, and Adams Counties, North Dakota: U.S. Geological Survey Open-File Report 79-564, 77 p.

Rehbein, E. A., 1978, Depositional environments and lignite resources of the Fort Union Formation, west-central North Dakota, in Williston Basin Symposium, 24th, Billings, 1978, The economic geology of the Williston Basin: Montana Geological Society, p. 295-305.

Royse, C. F., Jr., 1967, The Tongue River-Sentinel Butte contact in western North Dakota: North Dakota Geological Survey Report of Investigations 45, 53 p.

_____ 1970, A sedimentological analysis of the Tongue River-Sentinel Butte interval (Paleocene) of the Williston Basin, western North Dakota: Sedimentary Geology, v. 4, p. 19-80.

Wilder, F. A., and Wood, L. H., 1902, Report on the lignite by counties, in North Dakota Geological Survey Biennial Report 2, v. 1, no. 1, p. 159-161.