The Square Buttes Coal Field Oliver and Mercer Counties North Dakota

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GEOLOGICAL SURVEY BULLETIN 1076

Prepared as part of a program of the Department of the Interior for development of the Missouri River basin

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By WILLIAM D. JOHNSON, Jr., *and* ROBERT P. KUNKEL

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THE SQUARE BUTTES COAL FIELD, OLIVER AND MERCER COUNTIES, NORTH DAKOTA

By WILLIAM D. JOHNSON, JR., and ROBERT P. KUNKEL

ABSTRACT

The Square Buttes coal field comprises an area of about 720 square miles in Oliver and Mercer Counties in west-central North Dakota. It is bounded on the east and northeast by the Missouri River and is named for the prominent buttes that rise about 400 feet above the western bank of the river. Center, the county seat of Oliver County, is near the middle of the field. The coal field, which is a broad gently rolling upland containing scattered areas of semibadlands, ranges in altitude from 1,640 feet to about 2,420 feet.

Formations exposed in the Square Buttes area are the Cannonball and Fort Union formations of Paleocene age and the Golden Valley formation of Eocene age. The oldest formation, the marine Cannonball, crops out mainly in the southeast and is composed of about 400 feet of shales and soft thin-bedded sandstones. The nonmarine Fort Union formation, which conformably overlies the Cannonball, is exposed over most of the area. It consists of about 520 feet of sandstone, shale, siltstone, and clay and contains all the coal beds of commercial value. Only 69 feet of the nonmarine Golden Valley formation, which conformably overlies the Fort Union, is discernible in the mapped area. The Golden Valley consists of silty shale, crossbedded sandstone, thin beds of lignite, and in its lower part has a conspicious marker bed. Glacial deposits from the Iowan, Tazewell, and Mankato ice sheets of Wisconsin age cover about half the area.

Five levels of terraces of Pleistocene(?) and Recent age, ranging from 5 to 135 feet above the river, occur in the Missouri River valley; four levels of stream terraces of the same age are present in the valley of Square Butte Creek; and terrace remnants occur along most of the other streams in the coal field. Other surficial materials of Recent age include alluvium, landslide debris, and intermittent pond deposits.

The Tertiary strata dip less than 1° in a northerly direction into the Williston basin. Minor flexures with less than 25 feet of closure interrupt the gentle dip. The maximum structural relief is 150 feet. Two exploratory wells were drilled in eastern Oliver County in 1942 and 1952 but neither well yielded traces of oil or gas.

Coal reserves in the Square Buttes field are estimated to be 3 billion tons in beds 2½ feet or more thick. About 64 percent of the coal, all of which is of lignite rank, is in four beds: the Hagel, Otter Creek, Red Butte, and Kuether. In 1952, only one mine, which supplied local fuel needs, was in operation.

INTRODUCTION

This investigation of the coal resources of the Square Buttes coal field is a part of the Department of the Interior program for the

development of the Missouri River basin. The coal field, comprising an area of about 720 square miles in west-central North Dakota, includes most of Oliver County and a small part of Mercer County. It is bounded on the east and northeast by the Missouri River, on the west by the 101° 45′ meridian, on the south by the Oliver-Morton County line, and on most of the north by latitude 47° 15′ (see fig. 1).

FIELDWORK AND ACKNOWLEDGMENTS

The western part of the coal field was mapped by the writers in 1950, assisted by G. N. Pipiringos and R. W. Roberts; the eastern part was mapped in 1951 with the assistance of W. L. Adkison and A. A. Meyerhoff.

The base map for the western part was compiled by planetable methods. The base for the eastern part, constructed from topographic maps of the Washburn, Turtle Creek, and Wilton quadrangles, was tied to the western part by means of a planetable triangulation net.

Land subdivisions were compiled from township plats of the U. S. Bureau of Land Management, but only a few section corner markers could be found; the corners, therefore, were assumed to be at the junction of section line roads, right of ways, and fences. Elevations for structure contours were obtained from U. S. Coast and Geodetic triangulation stations and bench marks.

Only coal beds 2 feet or more thick were mapped. Where the coal thins to less than 2 feet, the outcrop line on the geologic map (pl. 1) was discontinued. If the thinning is only for a short distance however, the outcrop line was not interrupted and the thinning is shown by the measured coal sections.

PREVIOUS INVESTIGATIONS

The general geology of this part of North Dakota is shown on maps published by Hayden (1857, p. 109–116; 1858, p. 139–158; 1863, p. 1–218; and 1872). Smith (1909, p. 15–25) made a reconnaissance of coal beds in the Washburn lignite field, which includes northeastern Oliver County. The area of the Square Buttes field was described in a report on the geology of south-central North Dakota by Leonard (1912 a) and in the more extensive report on lignite deposits of North Dakota by Leonard, Babcock, and Dove (1925). The southeast corner of Oliver County is included in the Bismarck folio (Leonard, 1912 b). Stanton (1920, p. 1) made a reconnaissance of the Fort Union-Cannonball contact in eastern Oliver County. The geology and coal resources of an area adjoining this coal field on the south were described in 1921 by Hancock. In 1952 Benson prepared a detailed report on the Knife River area, which is adjacent to the Square Buttes field on the north and west. The results of ground-

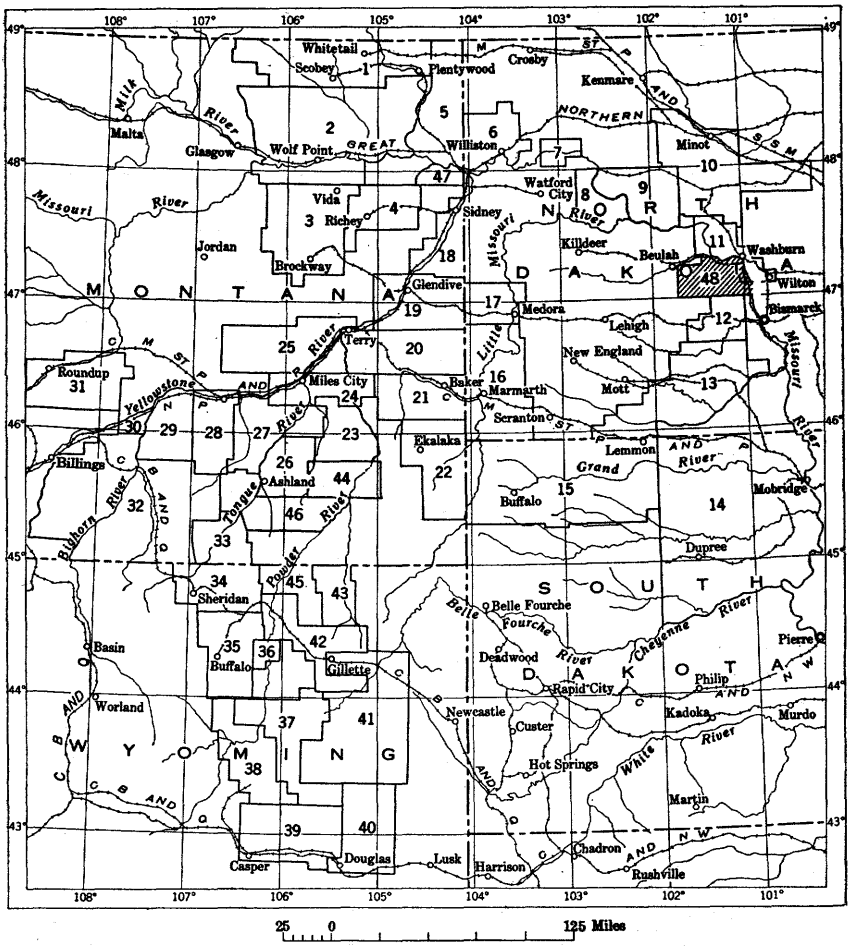


FIGURE 1.—Index map showing the location of the Square Buttes coal field and other coal fields in North Dakota and adjacent States.

COAL FIELDS OUTLINED IN FIGURE 1

No.	Field	Geol. Surv. Bull.
1	Scobey	751–E
2	Fort Peck	381–A
3	McCone County	905
4	Richey-Lambert	847–C
5	Culbertson	471–D
6	Williston	531–E
7	Nesson anticline	691–G
8	Fort Berthold	726–D
9	Fort Berthold	381–A, 471–C
10	Minot	906–B
11	Washburn	381–A
12	New Salem	726–A
13	Cannonball River	541–G
14	Standing Rock and Cheyenne River.	575
15	Northwestern South Dakota	627
16	Marmarth	775
17	Sentinel Butte	341–A
18	Sidney	471–D
19	Glendive	471–D
20	Terry	471–D
21	Baker	471–D
22	Ekalaka	751–F
23	Mizpah	906–C
24	Miles City	341–A
25	Little Sheep Mountain	531–F
26	Ashland	831–B
27	Rosebud	847–B
28	Forsyth	812–A
29	Tullock Creek	749
30	Area southwest of Custer	541–H
31	Bull Mountain	647
32	Big Horn County	856
33	Northward extension of Sheridan	806–B
34	Sheridan	341–B
35	Buffalo	381–B
36	Barber	351–I
37	Pumpkin Buttes	806–A
38	Sussex	471–F
39	Glenrock	341–B
40	Lost Spring	471–F
41	Gillette	796–A
42	Powder River	381–B
43	Little Powder River	471–A
44	Coalwood	973–B
45	Spotted Horse	1050
46	Birney Broadus	(1)
47	Northern part of Girard	(2)
48	Square Buttes	1076

[1] In preparation.

[2] Published as U. S. Geol. Survey Coal Inv. Map C 24.

water studies in Oliver County are contained in reports by Simpson (1937) and by Abbott and Voedisch (1938). Data on a test well drilled in eastern Oliver County in 1942 by the Carter Oil Co. were recorded by Ehlers (1943, p. 1618–1632).

GEOGRAPHY

The Square Buttes coal field is within the Missouri Plateau section of the Great Plains physiographic province (Fenneman, 1931, p. 61). The surface of the coal field has a maximum relief of 780 feet and is a broad, gently rolling land that rises gradually to rather broad stream divides. Locally, the divides are sharp, narrow ridges capped by beds of resistant sandstone; high buttes, such as Red Butte in secs. 21, 22, and 28, T. 143 N., R. 86 W., are conspicuous features along some of them.

The more prominent drainage divides are those between the Missouri and Knife Rivers, the Missouri and Heart Rivers, the Heart and Knife Rivers, and the Missouri River and Square Butte Creek. These divides are cut in places by glacial diversion channels. The highest point in the Square Buttes coal field is a prominent butte, altitude 2,420 feet, on the Heart River-Knife River divide in sec. 27, T. 141 N., R. 86 W.

A gently undulating upland surface, 160 to 360 feet above the flood plain of the Missouri, characterizes the north-central, northeastern, and eastern parts of the coal field. The altitude of this surface gradually increases westward to the Missouri River-Knife River divide and southwestward to the Missouri River-Square Butte Creek divide. The maximum relief from the lowest point near Hensler to the highest point, which is on the Missouri River-Square Butte Creek divide in sec. 29, T. 143 N., R. 83 W., is about 550 feet. The eastern edge of this upland has been intricately dissected by tributaries of the Missouri, and the larger streams, such as Alderin, Mandan Lake, and Sherk Creeks, have cut narrow, flat-bottomed valleys to a maximum of 150 feet below the surface.

In the southeast, the soft shales and sandstones of the Cannonball formation have been eroded to low hills and nearly barren "flats" below steep slopes of ridges and buttes capped by sandstone of the Fort Union. The weak Cannonball beds have slumped on some of the steeper slopes.

The valley of the Missouri River is a broad, deep, flat-bottomed trench. In Oliver County, the flood plain is roughly from ¼ to 1½ miles wide and is bordered by extensive terrace remnants.

Square Butte Creek flows in a deep, wide valley that becomes progressively more entrenched towards the Missouri River. Relief along the creek ranges from 140 feet to 300 feet; along its lower course the

country has been eroded into many narrow irregular spurs and into a few "badlands," typified by the area in the southwest corner of T. 141 N., R. 82 W.

In the west and northwest the country slopes northwestward from the hilly topography along the Knife River-Missouri River and Knife River-Heart River divides to a gently undulating glaciated plain of low relief along the north boundary of the area. The valley of Otter Creek, which has a flood plain 500 to 2,000 feet wide, bordered by well-formed terraces, is the most conspicuous feature in this part of the field.

The Heart River drainage basin is a broad southward-sloping plain of low relief. Most of the large streams head in glacial diversion channels and flow in broad, shallow valleys. Maximum relief within this area is about 150 feet.

DRAINAGE AND WATER SUPPLY

The Square Buttes coal field is drained by streams tributary to the Missouri, Knife, and Heart Rivers. The largest tributary, Square Butte Creek, flows across central and southeastern Oliver County and empties into the Missouri south of the area. In years of normal rainfall, the principal streams are perennial but their tributaries are intermittent.

Most water for domestic use is obtained from wells in the alluvial deposits in the larger stream valleys and from sandstone and lignite beds of the Fort Union formation. Only a few wells obtain water from the sandstones of the Cannonball formation, and glacial till is too thin and patchy to be a valuable source of ground water.

Water obtained from the Fort Union formation is commonly mineralized. The most abundant salts in ground water from the Fort Union and Cannonball formations are sodium sulfate, sodium chloride, and sodium bicarbonate. Much of the water is very hard because of the high content of calcium and magnesium salts. Most water obtained from coal beds contains iron and organic matter—both of which color the water and give it a disagreeable taste.

Numerous small, closed depressions scattered over the till-covered uplands contain water after heavy rains and spring thaws but usually dry up late in the summer. Small reservoirs for livestock use, built along most of the small streams, retain water throughout the dry season in years of normal rainfall.

CLIMATE AND VEGETATION

The climate of the Square Buttes coal field is characterized by long, severe winters and short, warm summers. The yearly precipitation averages about 16 inches, but the average for the period of

1940–50 was above the normal. More than 75 percent of the precipitation occurs in the months of April through September; June is the month of greatest precipitation. The prevailing wind is from the northwest. Temperatures in Center, N. Dak., are characteristic of the northern Great Plains. The average daily range is rather great, but readings over 100°F occur only about once a year. For the period of 1940–50 the average annual temperature at Center was 39.8°F. July, the hottest month during that period, had an average temperature of 68.4°; January, the coldest month, had an average of 9.1°.

Many species of grass, the characteristic vegetation of west-central North Dakota, are found on the varied soils within this area. Natural forest, consisting principally of cottonwood, ash, and willow, is confined to the bottom lands along the larger streams.

POPULATION AND INDUSTRY

The 1950 census gives the population of Oliver County as 3,091—a decrease of about 20 percent since 1940. Center, the county seat of Oliver County, had a population of 492 in 1950. The Price post office and the villages of Sanger, Hensler, and Fort Clark are on the branch line of the Northern Pacific Railway along the Missouri River; the village of Hannover is at the junction of State Highways 25 and 31.

A system of mixed farming is practiced in this part of North Dakota. The cash crop is primarily wheat; additional income is obtained by raising beef cattle or dairy herds. Some of the land is used to grow forage crops for winter feed.

A small amount of coal for local use is mined in the area. The only commercial production in 1952 was from a small strip mine near the town of Center. A few farmers strip a small amount of coal from open pits for their own use.

ACCESSIBILITY

Many section-line roads tie this area to two State highways that connect the coal field with surrounding towns. From Mandan, State Highway 25 extends 36 miles north and west to Center, and then westward for 6 miles to the junction with State Highway 31 at Hannover. State Highway 25 is paved from Hannover northward to Stanton; State Highway 31, a graded and graveled road, begins at Hannover and extends southward to the South Dakota State line. This road between Hannover and New Salem, and that part of State Highway 25 north of Hannover, are a part of the highway system that was built recently to connect U. S. Highway 10 with Garrison Dam on the Missouri River about 17 miles north of the Square Buttes field. New Salem is located about 9 miles south of the

coal field at the junction of U. S. Highway 10 and State Highway 31. The only bridge across the Missouri in this general area is at Bismarck, but the river can be crossed by ferry at Stanton.

The Killdeer Branch of the Northern Pacific Railway extends northward from Mandan and parallels the Missouri along the east side of the area to Stanton, about 5 miles north of the coal field. There, it turns westward and continues through Hazen and Beulah to Killdeer, N. Dak.

STRATIGRAPHY

TERTIARY SYSTEM

PALEOCENE SERIES

CANNONBALL FORMATION

The oldest formation exposed in the Square Buttes coal field is the Cannonball formation of Paleocene age. Rocks of this formation, the youngest marine strata known in the northern Great Plains region, were described originally by Lloyd (1914, p. 7, 9–10) from exposures along the Cannonball River in Morton County, N. Dak. Lloyd mapped this stratigraphic unit as the Cannonball marine member of the Lance formation and tentatively classified it as of early Tertiary age. In a more thorough study published in 1915 Lloyd and Hares classified the Cannonball as Eocene(?).

The age of the Cannonball then became the subject of much controversy: in subsequent reports the Cannonball and its continental equivalent, the Ludlow member of the Lance formation, were referred to as (1) Cretaceous (Stanton, 1920, p. 18) and (2) Tertiary (Winchester, Hares, Lloyd, and Parks, 1916, p. 18–19; Leonard, 1919, p. 13, 14; Hares, 1928, p. 14). In 1938 the Geological Survey referred the Cannonball marine member of the Lance formation to the Upper Cretaceous (Wilmarth, 1938, p. 336). Studies by Dorf (1937, p. 275; 1938, p. 33, 35, fig. 8; 1940, p. 233) and by Brown (1938, p. 421–422) have shown that the boundary between the Cretaceous and Paleocene should be placed at the base of the non-dinosaur-bearing Tullock and Ludlow members of the Fort Union formation and their equivalents elsewhere. Stephenson and Reeside suggested in 1938 that the Cannonball might be Paleocene. Dorf (1940, p. 231) observed that some of the invertebrates of the Cannonball resemble or are identical with species from the Midway (Paleocene) and Wilcox (Eocene) groups of the Gulf Coast. From their study of the Foraminifera of the Cannonball, Fox and Ross (1942, p. 672) concluded that the Cannonball is equivalent to the Midway group, which is Paleocene in age. The Geological Survey now considers the Cannonball and the Ludlow, which is the nonmarine stratigraphic equivalent of the Cannonball, to be Paleocene in age (Brown, 1949).

The Cannonball formation crops out along the Missouri River and Square Butte Creek in the eastern and southeastern parts of the coal field. The northernmost exposure of the formation in this area is under a terrace along the river in sec. 36, T. 144 N., R. 82 W., but the Cannonball is better exposed across the river near the town of Washburn. From Washburn the contact between the Cannonball and the overlying Fort Union formation extends upstream and crosses the Missouri between the villages of Hensler and Fort Clark. This location of the contact agrees with that mapped by Stanton (1920, fig. 1, p. 2). Hayden, in 1863, traced the Cretaceous-Tertiary boundary—that is, the contact of the Fox Hills sandstone and Fort Union formation—up the Missouri almost to the site of Washburn. The beds that he identified as Fox Hills are now known to be those of the Cannonball. On a later map (Hayden, 1872) he extended the contact to Fort Clark. In several reports Leonard (1912, pl. 9; 1917, p. 232) showed the contact between the Fort Union and Lance formations crossing the Missouri River a few miles south of Washburn. Thom and Dobbin (1924, p. 495) reported beds of the Tongue River member of the Fort Union formation in the Missouri valley above Fort Clark.

In the Square Buttes coal field the Cannonball formation consists of interbedded slightly sandy olive-gray marine shale and soft thin-bedded fine-grained light-gray to dusky-yellow sandstone. The sandstone commonly contains small orange-weathering sandy concretions. Large oval "cannonball" concretions, many 3 to 4 feet long, are found in the bluff on the Missouri River about 1 mile south of Price. Many of these concretions contain *Teredo* burrows in fossil wood. Conspicuous sandstones, like those to the south along the Heart River, are not present in the Cannonball in this area.

About 250 feet of the Cannonball formation is exposed along the Missouri River in the southeast corner of Oliver County. The Cannonball is 400 feet thick in the Emma L. Semling well in sec. 18, T. 141 N., R. 81 W.

The Cannonball commonly crops out in low, rounded hills and under ridges capped by sandstone of the Fort Union. Where the overlying sandstones have been removed by erosion, the Cannonball has been reduced to broad flats sparsely covered with vegetation. The bare outcrop has a checkered and broken appearance and is commonly covered with small selenite crystals. The area underlain by the Cannonball has a dull-gray cast, which is in distinct contrast to the overlying light-colored Fort Union strata.

No fossils were collected from the Cannonball formation by the writers, but Meek and later Stanton collected and described fossils from several localities in the area. Stanton (1920, p. 19, 20, 25–26,

29, 31–33, 36, 39, 44, 49) collected the following fauna from the west bank of the Missouri River about 1 mile south of Price and 19 miles north of Mandan, N. Dak.:

Solemya bilix
Nucula planimarginata
subplana
Crenella elongata
Corbicula berthoudi
Callista (Dosiniopsis?) deweyi
(Dosiniopsis) nebrascensis
Panope simulatrix
Lunatia obliquata
Anchura (Drepanochilus) perveta
Fasciolaria? (Mesorhytis) dakatensis
Lamna cuspidata

Meek (1876, p. 262, 264) collected *Teredo selliformis* and *Teredo globosa* from "near Fort Clark." As the only known marine beds in the vicinity belong to the Cannonball, these fossils must have come from that formation.

The Cannonball formation thins westward and interfingers with the continental deposits of the Ludlow member of the Fort Union formation. The western limit of the Cannonball is near the Little Missouri River in western North Dakota. Sediments of the Cannonball were laid down in a sea that persisted from Fox Hills (Late Cretaceous) through Cannonball (Paleocene) time east of the main area of deposition of the continental Late Cretaceous Hell Creek formation in eastern Montana and western North Dakota. A minor westward advance of this sea in early Hell Creek time was accompanied by the deposition of a 30-foot bed of marine strata which Cobban (Seager and others, 1942, p. 1418) recognized near the mouth of the Cannonball River in North Dakota. This unit has been called the Breien member of the Hell Creek formation by Laird and Mitchell (1942, p. 14). The retreat and disappearance of the Cannonball sea brought to a close marine sedimentation in the northern Great Plains.

Partial section of the Cannonball and Fort Union formations, NE¼ SW¼ sec. 34, T. 142 N., R. 81 W.

Fort Union formation:	*Feet*	*Inches*
Sandstone, yellowish-gray to dusky-yellow, fine- to medium-grained, thin-bedded, ledge-forming	21	-----
Sandstone, dusky-yellow to yellowish-gray, very fine grained, friable; contains bright yellowish-orange-weathering streaks; some very thin partings of light olive-gray, slightly carbonaceous shale	6	4
Total	27	4

Partial section of the Cannonball and Fort Union formations, NE¼ SW¼ sec. 34, T. 142 N., R. 81 W.—Continued

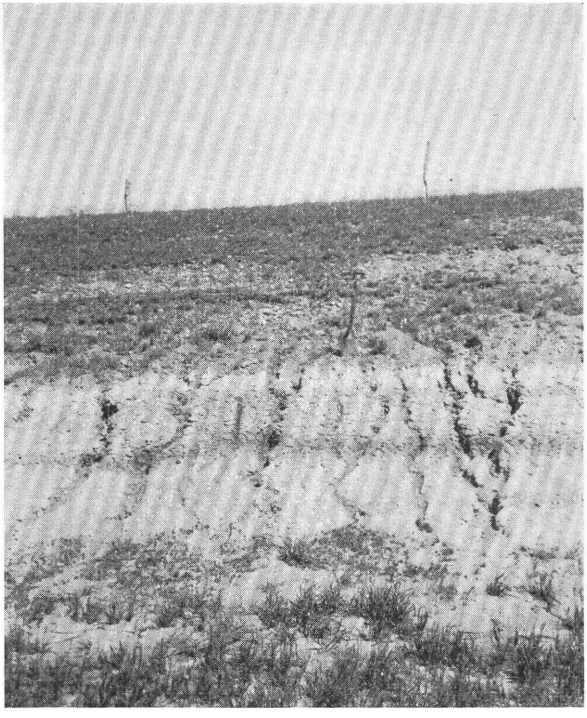
	Feet	Inches
Cannonball formation:		
Shale, grayish-olive to olive-gray, slightly sandy, fissile; some medium yellowish-brown sandy shale	16	3
Shale, moderate olive-brown to olive-gray, very slightly sandy, in beds 1–4 inches thick, intercalated with dusky-yellow very fine grained sandstone, in beds 1–8 inches thick; sandstones become thicker and more abundant in upper part	23	3
Shale, moderate olive-brown to olive-gray, slightly sandy; scattered partings of dusky-yellow sandstone; few very thin partings of grayish-brown shale; shale and sandstone slightly carbonaceous along bedding planes	18	10+
Total	58	4+

Partial section of the Cannonball and Fort Union formations, NW¼ SW¼ sec. 3, T. 140 N., R. 82 W., Morton County

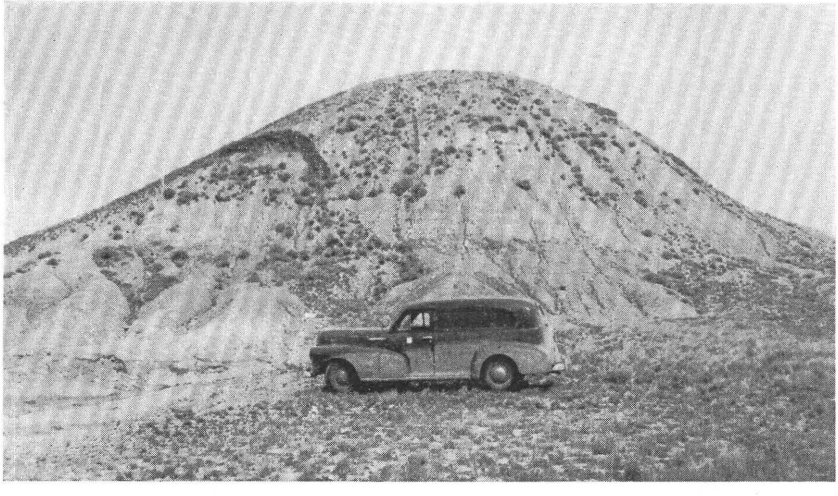
	Feet	Inches
Quaternary terrace deposit.		
Fort Union formation:		
Sandstone, dusky-yellow to light olive-gray, fine-grained, friable; contains small yellowish-orange-weathering concretions	4	6
Cannonball formation:		
Shale, light olive gray, slightly sandy, in beds 2–3 inches thick, and moderate olive-brown sandstone, in beds 1–2 inches thick; a few beds as much as 6 inches thick; sandstones thicker and more abundant in upper part; shale in upper part contains traces of carbonaceous material on bedding planes	36	6
Shale, grayish-olive, sandy; few thin partings of moderate olive-brown, sandy shale and moderate olive-brown sandstone that weathers bright yellowish-orange; small selenite crystals	21	-----
Shale, light to dark olive-gray, slightly sandy; interbedded with very thin beds of very fine grained light-gray to dusky-yellow sandstone, containing bright yellowish-orange-weathering concretionary specks	2	0+
Total	59	6+

Partial section of the Cannonball and Fort Union formations, NW¼NE¼ sec. 22, T. 141 N., R. 82 W.

	Feet	Inches
Fort Union formation:		
Sandstone, yellowish-orange to dusky-yellow, fine-grained, friable; contains hard concretionary sandstone lenses as much as 4 feet thick and 10–15 feet long	26	0+
Cannonball formation:		
Shale, olive-gray, slightly sandy and carbonaceous; interbedded with light olive-gray to moderate olive-brown very fine grained sandstone that weathers yellowish orange; sandstones range in thickness from 2–10 inches, with few beds as much as 26 inches thick	14	9



A. Fort Union strata overlain by till. Shovel stands just above the contact. Exposure along State Highway 25 in the NW¼ sec. 14, T. 143 N., R. 85 W.



B. Lower part of the Golden Valley formation in the NW¼ sec. 27, T. 141 N., R. 86 W. The dark band just above the automobile is the Golden Valley marker bed.

Partial section of the Cannonball and Fort Union formations, NW¼NE¼ sec. 22, T. 141 N., R. 82 W.—Continued

Cannonball formation—Continued	Feet	Inches
Sandstone, light olive-gray, very fine grained; weathers dusky yellow and is stained bright yellowish orange along joints and bedding planes; interbedded with olive-gray to olive-black slightly sandy shale; sandstone and shale uniformly bedded; sandstone in beds 1–10 inches thick, and shale in beds 1–3 inches thick; the thicker sandstone beds contain hard, concentric-weathering concretions	42	0+
Total	56	9+

FORT UNION FORMATION

The Fort Union is the surface formation in most of the Square Buttes coal field. In this area the beds referred to the Fort Union are not divisible into separate units on the basis of color or lithologic character, although the formation includes beds that are probably equivalent to all or part of the Tongue River member and the Sentinel Butte shale member of the Fort Union formation in western North Dakota. The lithologic characteristics of the Fort Union strata in the Square Buttes field are unlike those of the typical beds of the Tongue River and Sentinel Butte members. Thom and Dobbin (1924, p. 495) reported that Tongue River strata occur in the Missouri valley above Fort Clark which is on the north edge of this coal field. In the adjoining Knife River area Benson (1952, p. 46) assigned the nonmarine beds of Paleocene age, which occupy a stratigraphic position similar to that of nonmarine strata in the Square Buttes area, to the Tongue River member of the Fort Union formation. Strata equivalent to part of the Sentinel Butte shale member of the Fort Union formation in western North Dakota are present in the Knife River area, but they cannot be distinguished from the Tongue River because the color contrast between the two members does not persist as far east as the Knife River area (Benson, 1952, p. 43).

The Fort Union formation consists of sandstone, shale, siltstone, clay, coal, and minor amounts of siliceous rock and quartzite. The sandstones are generally light gray to dusky yellow and yellowish brown, fine to medium grained, friable, and calcareous. The harder beds of sandstone are commonly thin bedded; in places the bedding is so well formed that the sandstones have been quarried for building stone. Concretions of limonite and siderite, ranging in thickness from less than an inch to more than 6 inches, are found in the sandstones. Weathering of these concretions stains the beds yellowish orange to yellowish brown. Crossbedding and ripple marks are rare. The shales are light to olive gray, yellowish brown, grayish brown, and black.

Most are silty to sandy, but a few are clayey, poorly fissile, and calcareous. Much of the shale, especially that immediately above and below a coal bed, contains carbonized plant fragments. Ironstone concretions are abundant in some of the shales. Siltstones, which form a minor part of the formation, are generally sandy and calcareous, and light gray to yellowish brown. Bluish-gray plastic clay is common just above and below the coal beds.

Scattered throughout the stratigraphic section, but more abundant in the upper part, are beds of silicified very fine grained sandstone and shale, from 1 to 36 inches thick. This siliceous rock forms a highly resistant light-gray or white outcrop. Most of the siliceous rock contains abundant internal molds of stems and roots, but none of the plant impressions have been identified. Thin beds of platy siliceous shale and sandstone, containing many plant impressions, are commonly associated with beds of lignite throughout the Fort Union section. One such siliceous bed and thin coal were traced for about 6 miles along the north side of the Square Butte Creek-Missouri River divide in T. 143 N., R. 84 W. Hares (1928, p. 34–36) has discussed in detail these siliceous rocks. The fossilized plant fragments in these rocks indicate that the beds are silicified soils or swamp mucks (Brown, 1948, p. 1269). Charles Milton (written communication) has suggested that the silica may have been derived from beds of volcanic ash. Boulders of the siliceous rock may be suitable for riprap material.

Much of the Fort Union is obscured by glacial till, especially in the northwestern, northern, and eastern parts of the area (pl. 2*A*). The best exposures of the formation are along Alderin and Mandan Lake Creeks and other tributaries of the Missouri and in the rough areas on both sides of Square Butte and Otter Creeks. In the southeast near Price, resistant sandstones about 200 feet above the base of the Fort Union cap high buttes and underlie the major stream divides in T. 141 N., R. 81 W., the southern part of T. 142 N., R. 81 W., and in the eastern part of T. 142 N., R. 82 W. A hard thin-bedded fine-grained dusky-yellow sandstone, 25 to 30 feet thick, crops out in Square Buttes. Most of the sandstones in the lower part of the Fort Union are fairly uniform in character, but some beds of coarse, conglomeratic sandstone are present. A well-cemented brown conglomeratic sandstone about 115 feet above the base of the formation forms prominent ledges and underlies the ridges in the area around the common corner of secs. 1, 6, 31, and 36, Tps. 141 and 142 N., Rs. 81 and 82 W. This bed is composed of pellets, as much as 4 inches in length, of very fine grained sandstone, clay galls, and ironstone concretions in a matrix of coarse sand. The clay galls and ironstones weather from the sandstone, leaving a pitted surface.

The resistant sandstones in the lower part of the formation give way westward to softer sandstones and shales higher in the stratigraphic section. The surface expression of these softer beds is primarily that of a rolling upland of moderate relief. Sandstone underlies most of the stream divides and generally weathers to smoothly rounded topographic features. Some sandstones are cemented sufficiently to erode as sharp, narrow ridges and small, low buttes. Such sandstone-capped ridges and buttes are prominent on the divide in secs. 5 and 8, T. 141 N., R. 83 W., along the Square Butte Creek–Kinneman Creek divide in secs. 21, 22, and 27, T. 143 N., R. 85 W., and along the Otter Creek–Brady Creek divide in T. 143 N., R. 86 W., where Red Butte, in secs. 21, 22, and 28, is the most conspicuous feature. The brown, coarse-grained, friable to well-indurated crossbedded sandstone capping Red Butte may be in the overlying Golden Valley formation, but because the Golden Valley was not recognized elsewhere in this part of the coal field, the sandstone was included in the Fort Union. Boulders of siliceous sandstone and shale cover many hills and buttes in the southwest part of the coal field, and are particularly abundant in secs. 15, 16, and 32, T. 141 N., R. 87 W. A thick bed of quartzite caps a prominent butte in secs. 29, 30, 31, and 32, T. 142 N., R. 86 W.

Accurate measurement of the thickness of the Fort Union formation in the Square Buttes field was impossible because of the low dip, changes in dip, and the broad area of outcrop. Based on the few measurements possible in the area, the thickness of the Fort Union, however, is estimated to be about 520 feet. In the Knife River area 550 to 575 feet of the Tongue River member is exposed (Benson, 1952, p. 65), but locally in the northeastern part of that area the Tongue River increases in thickness to about 750 feet. In the New Salem lignite field (Hancock, 1921, p. 10) the upper part of the Fort Union formation has been eroded and only 350 feet remains.

The Fort Union formation conformably overlies the Cannonball, and the contact is marked by a change in color and lithologic character. The olive-gray marine beds in the upper part of the Cannonball contrast sharply with the dusky-yellow sandstones at the base of the Fort Union. The contrast is further accentuated by the topography, for the Cannonball erodes to barren gray slopes and flats below the grass-covered hills and ridges underlain by sandstone of the Fort Union. The Cannonball strata are gradational into the overlying Fort Union formation, and in places it is difficult to distinguish the sandy shales in the uppermost Cannonball from the basal sandstones of the Fort Union.

Fossils collected by Stanton (1920, p. 32) near the top of a high butte 1 mile south of Price, in what he believed were basal beds of the Fort Union, were:

Corbula mactriformis,
Viviparus leai,
Campeloma multilineata,
Thumastus limnaeiformis

A light-gray friable crossbedded fossiliferous sandstone just below the top of a prominent butte in the NW¼ sec. 3, T. 141 N., R. 81 W., probably is the bed from which Stanton made his collection. This sandstone is about 200 feet above the base of the Fort Union.

The following sections show the general character of the Fort Union strata in the Square Buttes coal field:

Partial section of the Fort Union formation SW¼NW¼ sec. 8, T. 143 N., R. 84 W.

	Feet	Inches
Glacial till.		
Fort Union formation:		
Shale, bluish-gray, sandy; contains yellowish-brown oxidation streaks; becomes more sandy in upper part; weathers yellowish gray	17	-----
Shale, brown, carbonaceous	----	6
Clay, blue, carbonaceous	1	7
Shale, grayish-brown, carbonaceous; contains streaks of coal ¼ inch thick	----	7
Clay, blue, slightly carbonaceous	----	5
Shale, grayish-brown, carbonaceous, fissile; abundant plant fragments	----	4
Shale, bluish-gray; slightly carbonaceous in upper part; weathers yellowish brown in lower 3 feet	6	6
Coal	----	2
Shale, dark-brown, carbonaceous, blocky	----	8
Shale, brown; streaks of weathered yellowish-brown shale ¼ inch thick in lower part; becomes slightly carbonaceous toward top	7	-----
Shale, bluish-gray	6	-----
Shale, bluish-gray, sandy; contains yellowish-brown oxidized streaks	6	6
Coal	1	3
Shale, brown, carbonaceous	3	6
Clay, bluish-gray, shaly; sandy in part; contains abundant yellowish-brown streaks ¼ to 1 inch thick	11	4
Clay, bluish-gray; carbonaceous at base	5	8
Coal	----	10
Shale, bluish-gray, slightly sandy; contains yellowish-brown oxidized streaks; carbonaceous in upper part	3	0+
Total	72	10+

Partial section of the Fort Union formation, SW¼ sec. 5, and SE¼ sec. 4, T. 143 N., R. 83 W.

	Feet	Inches
Fort Union formation:		
Shale, dusky-brown, slightly carbonaceous	----	3
Coal	----	1
Siltstone, dusky-brown	1	3

Partial section of the Fort Union formation, SW¼ sec. 5, and SE¼ sec. 4, T. 143 N., R. 83 W.—Continued

Fort Union formation—Continued	Feet	Inches
Siltstone, yellowish-brown to gray, calcareous; shaly in upper part; weathers white	6	4
Siltstone, yellowish-brown, calcareous; limonite-stained streaks	----	8
Shale, grayish-green, slightly silty, calcareous, fissile	3	5
Siltstone, light-gray, sandy, calcareous, crossbedded	----	4
Shale, light-gray, slightly silty, calcareous; some yellowish-brown shale: sideritic concretions that weather dark yellowish orange	5	8
Limestone, yellowish-brown, silty to shaly; weathers medium brown to yellowish orange; grades laterally into calcareous silty shale	1	5
Shale, medium-gray, very clayey, calcareous, poorly fissile	2	4
Siltstone, light-gray, sandy, calcareous, massive	1	9
Shale, medium-brown, silty, calcareous, poorly fissile	2	8
Shale, coaly	----	1
Shale, light-gray, silty, slightly calcareous, blocky	4	9
Limestone, very light gray, concretionery; grades laterally into light-brown calcareous shale	1	4
Shale, medium-gray to yellowish-gray, calcareous	----	4
Shale, yellowish-orange, silty, calcareous; platy sideritic concretions	----	2
Shale, yellowish-brown, calcareous, fissile	----	4
Shale, dusky-brown, with plant fragments	----	1
Siltstone, light-gray, sandy, calcareous, massive, friable; becomes shaly toward top	4	1
Shale, yellowish-brown, silty, calcareous, poorly fissile	1	5
Shale, yellowish-orange, silty, calcareous, platy; sideritic concretions	----	2
Siltstone, yellowish-brown, sandy, calcareous; sideritic concretions	3	10
Shale, yellowish-orange, silty, slightly calcareous, massive; sideritic concretions	----	2
Shale, yellowish-brown, calcareous, fissile; interbedded with thin bands of calcareous shaly yellowish-orange sideritic concretions	3	5
Shale, dusky-brown; plant fragments	----	2
Shale, medium-gray, slightly silty, calcareous, blocky; sideritic concretions	4	5
Shale, yellowish-brown to medium-gray, silty, poorly fissile; calcareous near base; sideritic concretions	4	4
Shale, dusky-brown, sandy; streaks of coal; abundant plant fragments	----	4
Shale, dusky-brown, silty	----	2
Sandstone, yellowish-brown, fine- to medium-grained, friable, massive; calcareous at base	3	4
Sandstone, yellowish-brown, fine- to medium-grained, very calcareous, hard	1	-----
Sandstone, yellowish-brown, fine- to medium-grained, calcareous, friable	3	7
Shale, yellowish-orange to medium-brown, silty, calcareous, fissile; sideritic concretions	7	9

Partial section of the Fort Union formation, SW¼ sec. 5, and SE¼ sec. 4, T. 143 N., R. 83 W.—Continued

Fort Union formation—Continued	Feet	Inches
Shale, light-gray, slightly silty, fissile	----	3
Coal	----	3
Shale, dusky-brown, silty; plant fragments	----	5
Shale, very light gray to yellowish-gray, slightly silty, calcareous; abundant plant impressions	1	9
Shale, dark-gray to dusky-brown; plant fragments	----	4
Siltstone and shale, very light yellowish gray, sandy; 6-inch beds of limonite-stained clay in middle	5	8
Siltstone, light-brown, and dusky-brown shale and coal	----	2
Coal; fossilized wood at top	2	2
Shale, olive-gray, calcareous, blocky	3	1
Shale, yellowish-brown, silty, calcareous	3	6
Siltstone, medium-brown, sandy, calcareous; fossilized wood near top	5	6
Shale, yellowish-brown, silty, calcareous; thin limonite-stained zones	5	4
Shale, medium-gray, slightly silty, calcareous, poorly fissile	----	6
Shale, yellowish-brown, silty, calcareous, blocky	3	10
Coal	1	9
Shale, dusky-brown; abundant plant fragments	3	3
Coal	----	1
Shale, grayish-green, blocky	8	4+
Total	117	7+

EOCENE SERIES

GOLDEN VALLEY FORMATION

The Golden Valley formation of Eocene age crops out at two localities in the coal field. It was named by Benson and Laird (1947, p. 1166–1167) from exposures southwest of Golden Valley, N. Dak., and consists of beds known previously as the "unnamed member of the Wasatch" (Seager and others, 1942, p. 1416). Leonard (1906, p. 88) first described the beds of the Golden Valley formation as "light-colored Tertiary clays," and in a later paper (1911, p. 535) he included the unit in the Fort Union formation. In 1942 Seager and others classified these beds as the upper member of the Wasatch formation (Eocene); the Sentinel Butte shale was included as the lower member. In the Knife River area, Benson discovered specimens of the floating fern *Salvinia preauriculata* Berry near the base of this light-colored unit. According to Brown (1948b, p. 1169–1170), this fossil serves as an Eocene "index species," as he has never found any *Salvinia* in Paleocene formations of the Rocky Mountains and Great Plains. A Cretaceous species was found by Brown (1948b, p. 1169) in the "Laramie" formation (Lance) in Colorado. In his 1952 report Benson describes in detail the lithology and distribution of the Golden Valley formation in western North Dakota.

That part of the Golden Valley formation exposed in the Square Buttes area consists of light olive-gray, grayish-brown, and brownish-black slightly silty shale and carbonaceous shale, some yellowish-gray micaceous, fine-grained, crossbedded sandstone, and thin beds of lignite. The most conspicuous unit in the Golden Valley is an 11-foot dark yellowish-orange-weathering bed near the base of the formation. This marker bed is composed of olive-gray shale cut by many very thin dikes of fine-grained limonitic sandstone. The marker bed is well exposed on the west end of a high butte in sec. 27, T. 141 N., R. 86 W. (pl. 2*B*). Here, about 8 feet above the top of the marker bed is another, though not so conspicuous, light olive-gray orange-weathering shale. These two orange-weathering shales constitute the lower member of the Golden Valley as described by Benson and Laird (1947, p. 1166–1167). A peculiar reddish-brown coarse-grained friable sandstone is in the basal part of the Golden Valley formation in secs. 16, 17, 20, and 21, T. 141 N., R. 86 W. This sandstone, which weathers to small, round, loosely cemented nodules, occupies approximately the same stratigraphic horizon as the marker bed.

The best exposure of the Golden Valley is on the west end of the high butte in sec. 27, T. 141 N., R. 86 W. There, the upper part of the Fort Union and 69 feet of the Golden Valley crop out. To the northwest, Golden Valley strata underlie the stream divide in secs. 16, 17, 20, and 21, T. 141 N., R. 86 W. Vegetation obscures most of the outcrop, but along the road between secs. 17 and 20 the peculiar reddish-brown sandstone near the base of the formation is exposed. The sandstone that caps Red Butte may be part of the Golden Valley formation, but it was mapped as Fort Union.

Only the lower 69 feet of the Golden Valley formation is present in the Square Buttes coal field. The formation is about 180 feet thick at its type locality in the Knife River area, but its original thickness is not known because the formation was eroded before deposition of the White River group of Oligocene age.

Because the Golden Valley grades upward from the underlying Fort Union formation, the contact in the Square Buttes area is arbitrarily drawn at the top of a thin coal bed about 5½ feet below the base of the marker bed. Specimens of the Eocene fern *Salvinia preauriculata* were collected from a thin shale above the upper orange-weathering shale in the section exposed on the butte in sec. 27, T. 141 N., R. 86 W. Although plant fossils are abundant in the shales immediately below the marker bed, *Salvinia* was not found.

The following measured section shows the lithology of the Golden Valley strata exposed in this area:

Partial section of the Fort Union and the Golden Valley formations NW¼ sec. 27, T. 141 N., R. 86 W.

	Feet	Inches
Glaciofluvial material.		
Golden Valley formation:		
Sandstone, yellowish-gray, fine-grained; contains hard finely crossbedded layers; ripple marks	2	3
Shale, light olive-gray to dusky-yellow, very slightly sandy; scattered sideritic concretions; more sandy in upper part	13	1
Coal	1	5
Shale, light olive-gray; sandy in lower part; scattered sideritic concretions	13	11
Shale, grayish orange-pink; abundant plant fragments, including *Salvinia preauriculata*	----	3½
Shale, grayish-brown, carbonaceous	----	2
Coal	----	9
Shale, grayish-brown, very carbonaceous	1	5
Shale, light olive-gray; cut by dikes less than 1 inch thick of fine-grained limonitic sandstone; weathers yellowish orange	11	4
Shale, dusky-brown to brownish-black, carbonaceous; few thin seams of coal	1	10
Shale, olive-gray; abundant plant fragments	----	10
Shale, brownish-gray; thin beds of medium yellowish-brown shale	2	11
Shale, dusky yellowish-brown, carbonaceous; two 1-inch coal seams	----	7½
Shale, brownish-gray, interbedded with layers of medium yellowish-brown shale	1	10
Shale, light olive-gray; cut by numerous irregular dikes less than 1 inch thick of fine-grained limonitic sandstone; weathers dark yellowish orange; this is the marker bed	11	---
Shale, light olive-gray, slightly silty; abundant well-preserved plant fragments; scattered selenite crystals	2	10
Coal	----	7
Shale, light olive-gray, slightly silty; abundant well-preserved plant fragments; scattered selenite crystals	2	1
Total	69	2
Fort Union formation:		
Coal, interbedded with seams of grayish-brown to brownish-black carbonaceous shale	1	4½
Shale, grayish-brown, very slightly sandy, carbonaceous, blocky	----	2½
Sandstone, yellowish-gray to moderate yellowish-brown, fine- to medium-grained, friable; shaly in part; upper 2 feet brownish-gray sandy shale	12	3
Total	13	10

QUATERNARY SYSTEM

PLEISTOCENE SERIES

A mantle of glacial till, ranging in thickness from a trace to more than 40 feet, covers about half of the Square Buttes coal field. Most of the area east and northeast of Center is covered by till, and a

rather narrow irregular belt extends across the area north of the high divide between the drainage basins of Square Butte Creek and the Missouri and Knife Rivers. The more gentle slopes in the drainage basins of Otter, Brady, and Brush Creeks are covered with till. The till is very patchy in the Square Butte Creek drainage basin west of Center and in the southern part of the coal field that is drained by Hailstone and Sweetbriar Creeks. Erosion has stripped most of the till from the area underlain by the Cannonball formation in the southeast corner of Oliver County. Deposits of outwash material are associated with the till sheets, and many glacial melt water channels are filled with glacial diversion channel deposits.

STAGES OF GLACIATION

The Pleistocene deposits in the Square Buttes coal field were laid down by at least two, and probably three, ice sheets that advanced across this area during the Wisconsin stage of glaciation. Benson (1952, p. 103), who believes that during the Wisconsin stage three separate ice sheets, the Iowan, Tazewell, and Mankato, advanced across the adjoining Knife River area, cites the glacial and fluvial deposits in the Knife River Valley as evidence. According to Benson, there also is indirect evidence of a pre-Wisconsin advance, probably Illinoian, but no deposits of that advance were found in the Knife River area. The southern part of the Knife River area probably was covered by only the early Wisconsin advances (Iowan and Tazewell), and most of the drift deposited by those ice sheets has been removed by erosion. The Mankato (late Wisconsin) advance covered only the northern and eastern parts of the Knife River area, where drift still mantles most of the slopes.

Leonard (1912a, p. 61–62) thought that only one ice sheet, which he attributed to the Kansan stage, advanced south and west of the Missouri River, but in a later paper (1919, p. 22) he stated that the deposits might prove to be younger. He also thought that the Altamont moraine marked approximately the western border of the Wisconsin drift sheet. At first Alden (1932, p. 86–87) agreed with Leonard about the age of the drift west of the Missouri River, but, a study of the glacial drift deposits of Iowa convinced him that the drift west of the Missouri was not older than the Illinoian and perhaps not older than the Iowan stage of glaciation (the Iowan is now a substage of the Wisconsin). According to Alden, none of the glacial drift on the plains of North Dakota and Montana shows signs of long exposure to weathering that is evident in the Kansan and Nebraskan drifts of eastern Nebraska and southern and western Iowa. Leverett (1917, p. 144) thought that the degree of preservation of the pre-Wisconsin drift near the Missouri River in North Dakota indicates an Illinoian or Iowan age for the drift.

If the glacial deposits in the Knife River area are related to the Iowan, Tazewell, and Mankato substages of the Wisconsin stage of glaciation as stated by Benson (1952, p. 103), then the writers believe that the glacial deposits in the adjoining Square Buttes area are also related to those three ice advances. The three Wisconsin tills in the Knife River area are similar lithologically (Benson, 1952, p. 194) and can be separated only on their extent and topographic expression. In the Square Buttes coal field only two drift sheets are seen readily, but the drift of early Wisconsin age probably includes deposits of both the Iowan and Tazewell advances. The remnant of the early Wisconsin drift is very thin and patchy and over a considerable area is represented only by glacial erratics. The extensive cover of late Wisconsin drift in the Square Buttes area is assigned to the Mankato substage. Deposits of the Cary substage of the Wisconsin, which is intermediate between the Tazewell and Mankato substages, were not recognized by Benson (1952, p. 184) in southern North Dakota.

Iowan and Tazewell drifts.—The Iowan and Tazewell drift is found south of the Mankato drift sheet in the southwestern part of the area and in a reentrant between two lobes of Mankato drift in west-central and south-central Oliver County (pl. 3). The northward-trending reentrant is about 12 miles long and from 2 to 6 miles wide. The belt of early Wisconsin drift in the southwestern part of the coal field is 1½ to 7½ miles wide. The probable limit of the Iowan ice sheet southwest of the coal field, as determined by Benson (1952, pl. 3), is shown on plate 3; the outer limit of the Tazewell drift is not known.

Mankato drift.—The Mankato drift border in the Square Buttes coal field as shown on plate 3, extends from sec. 30, T. 142 N., R. 87 W., on a sinuous course southeastward to sec. 25, T. 141 N., R. 86 W. From there it turns northward along the west side of the Knife River–Square Butte Creek divide to sec. 18, T. 143 N., R. 85 W. The high Square Butte Creek–Kinneman Creek divide across the south edge of T. 143 N., R. 85 W., marks the southern limit of the Mankato ice. The east margin of the reentrant in the Mankato drift border is difficult to determine, but the pattern of drift and the location of old diversion channels indicate that the margin of the lobe of Mankato ice that covered eastern Oliver County followed an irregular line across the east side of Tps. 141 and 142 N., R. 85 W. The southward advance of the Mankato ice across the Square Buttes area probably was hindered by the high divide along the south edge of T. 143 N., R. 85 W., and the ice was forced around the ends or over the lower parts of the divide. One lobe of the ice pushed southward across the area drained by Otter, Brady, and Brush Creeks. A series of glacial diversion channels and morainic features in T. 141 N., Rs. 86

and 87 W., mark the southern limit of this lobe. No marginal moraine was formed on the east side of this lobe of ice, but large glacial boulders are abundant along the west slope of the Knife River–Square Butte Creek divide. The western margin of the lobe of Mankato ice that covered eastern Oliver County is very indistinct. No laterial moraine was deposited, and the till laid down along the margin of the ice must have been thin and discontinuous, for it has been largely removed by erosion. In the northern part of the coal field the Mankato till is thicker and covers most of the uplands. No till sheet representing a small readvance of the Mankato ice, as described by Benson (1952, p. 103–104), was recognized in the northern part of the Square Buttes area; but deposits of such a readvance might be present. After mapping in the Square Buttes coal field, the writers have modified slightly Benson's (1952, pl. 3) location of the Mankato drift border in southwest North Dakota.

CHARACTER OF THE TILL

The till is composed predominantly of clay and sand derived locally from Fort Union and Cannonball rocks. Imbedded in the till are granules and pebbles, and some cobbles and boulders principally of limestone, igneous, and metamorphic rocks. In some exposures the granules and pebbles are mainly fragments of the local bedrock. The large boulders are generally granitic rocks. Fragments of coal, clinker, and fossilized wood are scattered throughout the till, which, when fresh, is dark bluish gray and calcareous.

In many areas where the till is scant or absent, the surface of the ground, particularly on the hills, along the ridges, and adjacent to old melt water channels, is covered with stones and boulders. These erratics are predominantly a concentrate that remained after removal of the finer constituents of the till, but at a few places, the glacial erratics may be a morainic feature in which little or no fine till was deposited originally. Glacial erratics were not mapped separately from the till, so the till-distribution pattern on the geologic map does not show all the occurrences of the erratics. Erratics are abundant along the old diversion channel in sec. 23, T. 141 N., R. 87 W., on the hummocky topography adjacent to the diversion channels in secs. 23, 24, and 26, T. 141 N., R. 86 W., and on hills in sec. 32, T. 142 N., R. 85 W. Glacial erratics also are scattered along the west side of the Knife River–Square Butte Creek divide in T. 142 N., R. 85 W.

GLACIAL DIVERSION CHANNEL DEPOSITS

The diversion channel deposits consist of glacial outwash material, mainly sand and silt and lenses of gravel filling channels cut by glacial melt waters, and deposits in preglacial drainage channels into

which melt waters were diverted. The average thickness of the channel deposits is not known, but at an exposure in sec. 20, T. 143 N., R. 83 W., the fill ranges in thickness from 12 to 22 feet within a few yards. The deposits are preserved best in the large diversion channels in the northern part of the coal field and in the series of channels in the southwestern part of Oliver County. Many of the present streams, such as Square Butte, Sherk, Kinneman, Brady, Otter, Brush, Hailstone, and Sweetbriar Creeks, served as channels for melt waters during the glacial periods. Their valleys were filled with outwash, much of which has since been scoured out by stream action. Alluvium of Recent age now covers most of the outwash in these stream channels.

Many diversion channel deposits in the old melt water channels grade laterally into the alluvium filling the present stream valleys; the boundary between the two deposits is indefinite. All the sediments mapped as diversion channel deposits in this area include some Recent alluvium that was deposited in the old channels by slope wash and by small intermittent streams. Most of the old melt water channels are floored with diversion channel fill, but in some channels the deposits are too small to map as a distinct unit. At several places, especially on the upland adjacent to the Missouri River, the diversion channel deposits are being actively eroded by tributaries of the Missouri, and in places have been cut into discontinuous remnants. Melt water from the Mankato ice sheet deposited most of the diversion channel fill in this area. Even those deposits that lie beyond the Mankato drift border are the result of runoff from the Mankato ice. Within the area of Mankato drift most of the diversion channel deposits appear to overlie till.

GLACIAL OUTWASH DEPOSITS

The outwash deposits mapped in the Square Buttes coal field occur as terrace remnants in or adjacent to former diversion channels. These terraces are remnants of an older fill that was largely scoured out of the channels before deposition of the material now filling the channels. The outwash deposits are most abundant along the old diversion channels south of Hensler, in the upper drainage basin of Kinneman Creek along the north border of the coal field, and along the diversion channels in the southwestern part of Oliver County. A large deposit of glacial sand and gravel caps the valley spurs high on the side of the Missouri trench in secs. 1 and 2, T. 143 N., R. 84 W., southwest of Fort Clark. Melt water from an ice sheet standing in the Missouri trench probably deposited this glacial outwash against the side of the trench. Because many of the present stream valleys served as channels for glacial melt water, and were filled with outwash material which was later eroded into terrace remnants, many of the stream terraces and outwash deposits are analogous. However, where

the terrace remnants lie adjacent to channels containing diversion channel fill, they were mapped as outwash.

The outwash deposits consist of scattered cobbles and boulders, stratified silt, sand, and gravel. The gravels, which commonly are subangular to subround and range from about ½ inch to 4 inches in diameter, are about 70 percent limestone, igneous, and metamorphic rocks, and 30 percent sandstone and sideritic concretions from the Fort Union. The Fort Union rocks are found mostly in the finer constituents of the deposits. The outwash deposits generally are from 3 to 10 feet thick, but some deposits 20 feet thick were found. Some of the scattered deposits in the area of Iowan and Tazewell drift may be products of those glacial advances, but most of the deposits are probably remnants of outwash from the Mankato ice sheet.

ESKERS

Two eskers, or esker-type deposits, were mapped in the Square Buttes area. The largest, in secs. 1 and 6, T. 141 N., R. 85 W., is a conspicuous ridge 1½ miles long and 50 feet higher than the surrounding country. This esker, which is shaped like a J, is composed of several segments, the largest forming the north end of the deposit. The sand, gravel, and scattered cobbles of the deposits are fairly well bedded. About 50 percent of the gravel-size materials in the esker are sideritic concretions from the Fort Union formation. The remainder of these materials are limestone and igneous rocks with minor amounts of quartzite and chert. Ferruginous material has stained the deposit a reddish brown. The esker, which was formed near the outer margin of the Mankato drift sheet, is surrounded by and apparently overlies till.

The other esker in the Square Buttes area is in secs. 14 and 15, T. 142 N., R. 83 W. This low and sinuous deposit is composed of four segments that trend southwestward in a line about 1 mile long. A stream has breached the esker near its southern end. Ferruginous concretions from the Fort Union formation make up a large part of the stratified material in the deposit, which also is surrounded by and probably overlies till. As the deposit is in the area covered with Mankato till, it is probably a deposit of that ice advance.

UNDIFFERENTIATED GLACIOFLUVIAL DEPOSITS

Low mounds of stratified sand, gravel, and silt are scattered over the Square Buttes coal field, both in the northern till-covered part and in the south where the till is very patchy. These deposits probably are outwash material, but because their true nature is not known they are mapped as undifferentiated glaciofluvial deposits. The collapsed bedding of the deposit on the township line between secs. 7 and 12,

T. 141 N., Rs. 85 and 86 W., is indicative of an ice-contact relation. Those glaciofluvial deposits that lie near old glacial diversion channels may be erosional remnants of older diversion channel fills. The deposits are at elevations from 1,960 to 2,425 feet above sea level and most appear to overlie till. About 80 percent of the material is limestone and igneous rock, and the other 20 percent is sideritic concretions and sandstone from the Fort Union. The deposits in sec. 4, T. 141 N., R. 85 W., and in sec. 10, T. 141 N., R. 86 W., contain an unusually high percentage of sideritic concretions. The poorly sorted glaciofluvial deposit capping the large butte in sec. 27, T. 141 N., R. 86 W., is overlain by numerous glacial erratics. It is assumed, therefore, that the marginal edge of the Mankato ice overrode this deposit after it was laid down. Small deposits of glaciofluvial sand and gravel occur in secs. 25 and 26, T. 143 N., R. 84 W., high on the north side of the divide between Square Butte Creek and the Missouri River. These deposits were probably laid down when the Mankato ice sheet stood close to the north side of the divide. Most of the glaciofluvial deposits are of Mankato age, but those scattered deposits in the area of Iowan and Tazewell drift probably are related to those advances.

PLEISTOCENE(?) AND RECENT SERIES

During the stages of advance and retreat of the ice sheets across this area and in the period since the final retreat of the Wisconsin ice, the Missouri River valley and the larger stream valleys in the coal field were filled with fluvial material. Streams have eroded these valley fills, forming many terraces at several levels along the valleys. Each terrace was mapped as a surface without regard to its ultimate elevation above the stream. In the Missouri River valley the writers recognized and mapped five distinct terrace levels (pl. 1). At most places the contacts between the terraces are distinct, but in the wide bend of the Missouri near Hensler the terraces blend. Wherever possible, the terraces along the tributary streams were correlated with terrace levels in the Missouri valley.

MISSOURI RIVER TERRACES

The lowest and youngest terrace (pl. 1) which is only 5 to 15 feet above river level, is well preserved on the inside of the meanders from Mandan Lake southward to the Morton County line. At places no distinct break exists between the alluvium and this terrace, which is covered by a sheet of silt and fine sand of Recent age.

The second terrace extends along the Missouri from Mandan Lake southward to Price. South of Price only three small remnants of this level were found. The second terrace, which is less than half a mile wide, ranges in elevation from 20 feet above the river between

Mandan Lake and Hensler to 55 feet near Sanger. The interval between the first and second terraces ranges from 10 to 30 feet. The second is composed of sorted sand and gravel overlain by silt and fine sand. Deposits of this terrace rest on beds of the Cannonball formation east of Hensler and around Sanger and appear to overlie till in secs. 5 and 6, T. 142 N., R. 81 W.

The most extensive terrace level along the Missouri River in the Square Buttes area is the third level (pl. 1). This terrace, which stands 30 to 80 feet above the river, forms an almost continuous surface along the west side of the river. Only in the extreme southeast corner of the coal field has the terrace been completely removed by erosion. For short distances between Fort Clark and Mandan Lake, however, it is very narrow or missing. The third terrace is of greatest extent in the wide bend of the Missouri River around Hensler, where it is about 1½ miles wide and the surface reaches a maximum elevation of 75 feet above the river; it includes some small patches of the fourth terrace. Benson (1952) designated the third terrace as the alluvial terrace on the Missouri River on his map of the Knife River area. The terrace is composed of poorly bedded to well-bedded silt, sand, and gravel, capped by a layer of yellowish-gray silt 3–7 feet thick. Most of the gravels are limestone and igneous rocks. Subangular to subrounded cobbles and boulders of sandstone from the Fort Union are found in the terraces near the high sandstone-capped buttes south of Price. Deposits of the third terrace overlie and are interbedded with till, but at several places along the river south of Hensler the deposits rest on Cannonball strata.

Remnants of the fourth terrace are scattered along the west side of the Missouri valley 60 to 135 feet above the river but are most abundant around Fort Clark and south of Price. West of Fort Clark the fourth continues northward into the Knife River area. The interval between the third and fourth terraces west of Fort Clark is about 40 feet. Between Fort Clark and Mandan Lake the fourth terrace is high and irregular and includes small remnants of the fifth terrace. Just south of Hensler, remnants of the fourth terrace, which are a maximum of 60 feet above the third terrace, form low hills rather than a terrace profile. In that area small patches of till overlie some of the fourth terrace deposits. East of Hensler, in the wide bend of the Missouri River, this terrace rises gradually from the level of the third to a height of 100 feet above the river; the contact between the two terraces is difficult to determine. The only remnants of the fourth between Sanger and Price are in sec. 8, T. 142 N., R. 81 W., at an altitude of 90 feet above the river. The fourth terrace is extensive south of Price, where it ranges from 80 to 135

feet above the river and 25 to 60 feet above the third level. The highest remnants of this terrace are in secs. 2, 11, and 14, T. 141 N., R. 81 W.

The gravel-sized particles, which predominate in the fourth terrace, are composed of limestone, igneous rocks, and quartzite. Fragments of sandstone and sideritic concretions of the Fort Union are found in the sand-sized particles and in gravels less than 1 inch long. The gravels are subround to round and range from ½ inch to 3 inches in length. Scattered cobbles 5 to 8 inches long are present in the deposits. The terrace deposit in secs. 2 and 3, T. 143 N., R. 82 W., that is questionably assigned to this level, overlies till which is underlain by sand and gravel of glacial origin. Remnants of the fourth terrace in sec. 8, T. 142 N., R. 81 W. rest on till. The deposits south of Price apparently lie directly on beds of the Cannonball.

The highest terrace remnants along the Missouri River in the Square Buttes field belong to the fifth level. These remnants, which are 120 to 180 feet above the river, are found only at three places. The fifth terrace is best preserved west of Fort Clark in secs. 34 and 35, T. 144 N., R. 84 W., and sec. 2, T. 143 N., R. 84 W. In sec. 1, T. 143 N., R. 84 W., the poorly preserved remnants of this level are difficult to distinguish from the glacial outwash that caps the valley spurs. The only remnant of the fifth terrace between Fort Clark and Price is in sec. 5, T. 143 N., R. 83 W. Two small deposits of terrace material, one in sec. 2 and the other in sec. 11, T. 141 N., R. 81 W., are correlated with the fifth level. These deposits slope up gradually from the fourth terrace to a height of 160 to 180 feet above the river. A gravel pit in the deposit in sec. 11, T. 141 N., R. 81 W., exposes 6 feet of well-bedded coarse sand containing scattered lenses of gravel, principally of igneous rocks less than 2 inches long.

SQUARE BUTTE CREEK TERRACES

No attempt was made to correlate the terrace remnants along the tributaries of Square Butte Creek with the four main levels found within the creek valley. All terrace deposits consist of stratified sand and gravel capped by a layer of silt or fine sand. Limestone and igneous rocks constitute the larger part of the gravels, but in a few deposits locally derived sideritic concretions and sandstone are most abundant. The gravels are subangular to well rounded.

The youngest and lowest terrace (pl. 1) is 10 to 20 feet above the stream. Remnants of this terrace are scattered along the valley but are most abundant on the west side of T. 142 N., R. 83 W. Remnants of the second terrace, which are from 20 to 35 feet above the stream, are found mainly in T. 141 N., R. 82 W., and in a small area near the creek between T. 142 N., Rs. 83–84 W. The interval between the first and second terraces is 15 to 20 feet. The third terrace is the most

extensive along Square Butte Creek. Remnants of this terrace are along the creek from the northeast corner of T. 142 N., R. 85 W., southeastward to the Morton County line. This surface, which is 40 to 60 feet above the creek, apparently grades downstream into the fourth terrace, Qtm_4, in the Missouri valley. Deposits of the third terrace range in thickness from 4 to 12 feet. Remnants of the fourth level, the highest terrace, are mainly in T. 141 N., R. 82 W. and in the NE¼ of T. 141 N., R. 83 W. Three small remnants of this terrace also are present just west of Center in secs. 15, 16, and 22, T. 142 N., R. 84 W. The fourth terrace is 65 to 80 feet above the creek and 15 to 20 feet above the third. Both the third and fourth overlie Mankato till at several localities along Square Butte Creek. Deposits of the third rest on till in sec. 7, T. 141 N., R. 82 W., and also appear to overlie till in sec. 1, T. 141 N., R. 83 W., and in sec. 1, T .142 N., R. 85 W. Deposits of the fourth terrace in sec. 2, T. 141 N., R. 83 W., and in sec. 22, T. 141 N., R. 82 W., appear to have been laid down, at least in part, on till.

SHERK CREEK TERRACES

The stream-cut terraces along Sherk Creek are at four levels; the lowest terrace (pl. 1) stands 5 to 15 feet above the stream, the second 25 to 40 feet, the third 40 to 50 feet, and the fourth 50 to 60 feet. The third terrace is apparently equivalent to the third terrace level in the Missouri valley. Because Sherk Creek served as a glacial melt water channel during the Pleistocene, the terrace deposits contain a great amount of materials once carried by the ice sheets.

TERRACES ALONG UNNAMED CREEK IN T. 141 N., R. 85 W.

Two distinct terrace levels were recognized along the tributary of Sweetbriar Creek in T. 141 N., R. 85 W., but no attempt was made to correlate those terraces with terrace levels along other lines of drainage in the coal field. The two terraces stand 10 to 15 feet and 30 to 40 feet, respectively, above the stream. Rock materials transported into the area by the glaciers constitute 65 to 70 percent of the gravel-sized particles in the deposits. Limestone is the most abundant rock, but fragments of sideritic concretions from the Fort Union formation are common. The weathered sideritic concretions stain the deposits a reddish brown.

UNDIFFERENTIATED TERRACES

Although terraces along Otter Creek are extensive and range in elevation from 15 to 75 feet above the creek, upstream they tend to merge and cannot be distinguished from one another. The deposits consist of stratified coarse sand and gravel with cobbles and some boulders 1 foot long. From 50 to 65 percent of the gravels are ma-

terials brought to the area by the ice sheets. Fragments of sideritic concretions are abundant and in places have stained the deposits a dark reddish brown.

Composition of the isolated terrace remnants along the minor streams is directly related to the strata eroded by the streams. Although gravels reworked from glacial deposits are present in all terrace deposits, the stream-cut terraces in the southern part of the coal field contain more rock fragments from the Fort Union than do the terrace deposits in the north where the Fort Union is covered by till.

Many of the terraces along Otter, Brady, and Brush Creeks overlie till, and in a few places till and terrace material are interbedded.

ALLUVIUM

The alluvial material flooring in the Missouri River valley and most other stream valleys in the area is of Recent age. The band of alluvium along the south and west side of the Missouri River is generally ¼ to ½ a mile wide, but in the wide bend of the river near Hensler it increases in width to a maximum of 1½ miles. At several places along the valley the river has removed the alluvium by undercutting its bank. Narrow bands of alluvium are found along most of the streams in the area, but only the more extensive deposits are shown on the geologic map. Included in the alluvium are some low benches of alluvial material, mainly silt, which are not more than 10 feet above the stream.

Where former glacial melt water channels spilled into the present stream valleys, the diversion channel deposits grade laterally into the Recent alluvium; so the boundary between the two deposits was drawn arbitrarily . The surface of the alluvium along several of the tributaries of the Missouri is graded to Missouri River terraces rather than to the alluvium of the river itself. The alluvium along the stream flowing across secs. 33, 34, and 35, T. 143 N., R. 84 W., is continuous into the third terrace (pl. 1), west of Fort Clark, and that along the stream flowing just east of Hensler is also continuous into the third terrace. The alluvium in the valley of Sherk, Creek and along the large stream just south of Sherk Creek is graded to the second Missouri terrace.

The Recent alluvium consists of silt, fine to coarse sand, gravel, and a few cobbles and boulders. A pit in the alluvium of Square Butte Creek in sec. 8, T. 142 N., R. 84 W., exposes 15 feet of irregularly bedded, medium- to coarse-grained yellowish-gray sand and gravel. Limestone and igneous rocks constitute 57 percent of the gravel-sized particles and the remainder are fragments of sandstone and sideritic concretions. Fragments of weathered coal, clinker, and fossilized wood are common in the alluvium.

Thickness of the Missouri alluvium in the Square Buttes area is unknown. Benson (1952, p. 220) reports that the fill in the Missouri valley at Garrison Dam, which is about 17 miles north of the Square Buttes area, is 100 to 125 feet thick.

LANDSLIDE MATERIAL

Five landslide masses, the largest of which is almost half a mile long, are prominant features below Square Buttes and other high, steep-sided buttes in secs. 2 and 3, T. 141 N., R. 81 W. Gradual slumping of the mass in the northeast corner of sec. 3 has crumpled the bedding in the third terrace deposit northeast of it.

Gradual movement of the landslide in sec. 33, T. 141 N., R. 81 W., has shifted the course of a small stream southward around the southern end of the mass. The topography of the slides is characterized by low hummocky ridges separated by long enclosed depressions; both ridges and depressions strike roughly perpendicular to the direction of mass movement. Integrated drainage has not been established in the slide areas, but some streams have cut into the slides by headward erosion. The sandstones of the Fort Union and the soft, weak shale of the Cannonball formation are the rocks in the landslides, which are of Recent age. The mass in the northeast corner of sec. 3, T. 141 N., R. 81 W., is younger than the third Missouri terrace upon which it is encroaching.

INTERMITTENT POND DEPOSITS

At several places large intermittent ponds are being filled with dark brown fine sand and silt. These windblown and slopewash deposits are probably less than 10 feet thick. During periods of dry weather, they are commonly covered by a thin crust of caliche. The largest deposit, which is in secs. 11 and 14, T. 141 N., R. 85 W., occupies a depression in an old glacial diversion channel. Other deposits occur in secs. 24 and 25, and in sec. 27, T. 141 N., R. 87 W. The large depression in secs. 2, 3, and 11, T. 143 N., R. 85 W., is occupied in part by a pond.

DRAINAGE DURING THE PLEISTOCENE

Before the spread of continental ice from Canada southward into Montana and the Dakotas during the Pleistocene, the Heart and Knife Rivers in central North Dakota apparently flowed eastward down the slope of the plains, just as they do now. The preglacial Missouri River, however, with its tributaries, the Yellowstone and Little Missouri Rivers, flowed northeastward to Hudson Bay (Flint, 1947, p. 164), and the divide between the Missouri River drainage and that of the streams in central North Dakota probably trended slightly east of north across the western part of the State.

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Evidence of Nebraskan and Kansan glaciation in this part of North Dakota has not been found, and it is doubtful that those glaciers advanced this far westward in the State. The Nebraskan and Kansan ice sheets certainly must have blocked the eastward-flowing streams, but no record of those drainage changes is known, because the land surface during those stages of the Pleistocene doubtlessly stood at a higher elevation than it does today, and it probably was destroyed by later erosion.

The greatest change in the drainage pattern in eastern Montana and the Dakotas probably took place during the Illinoian stage. The southward and westward flow of the Illinoian glacier diverted the Missouri River from its course to Hudson Bay to a southeasterly course across the Dakotas. Deposits of the Illinoian glacier have not been recognized in central North Dakota, although the glacier must have stood for a considerable time adjacent to what is now the east side of the Missouri River trench. The great volume of water discharged across this area must have eroded the soft bedrock very rapidly, and on retreat of the glacier the Missouri River was flowing through a trench too deep to be abandoned in favor of its old course to Hudson Bay.

Various dates have been ascribed for the diversion of the Missouri River: Wisconsin (Todd, 1923, p. 470), Kansan or Nebraskan (Alden, 1932, p. 58), Kansan (Flint, 1949, p. 71), and Illinoian (Warren, 1952, p. 1154; Crandell, 1953, p. 588). From work in South Dakota, Warren has demonstrated that at least part of the Missouri River trench is of Illinoian age and in his later paper on the Pleistocene geology of eastern South Dakota Flint (1955, p. 143) tentatively accepts this age. If the Illinoian age of the Missouri River trench is valid in South Dakota, then probably it applies also to North Dakota.

At the close of the Sangamon interglacial stage the Iowan glacier flowed into central North Dakota, entered the Missouri River trench, and spread considerably west of the river. The maximum westward extent of this ice sheet probably was greater than that of any later glacier. Blocking of the Missouri River trench diverted the flow of the Missouri, Yellowstone, and Little Missouri Rivers across west-central and south-central North Dakota in a system of diversion channels that extends from the north end of the Killdeer Mountains southeastward through Hebron and Glen Ullin to Fort Yates, N. Dak. Leonard (1916, p. 299) first described this diversion channel system; Benson (1952, p. 176–179) slightly modified Leonard's work. As the Iowan glacier retreated eastward, the Missouri River trench was uncovered, and the drainage re-established in the trench, cutting off the flow of water into the diversion channel system.

The age of this temporary diversion of the Missouri River drainage is controversial. Alden (1932, p. 89) assumed that it was caused by the Illinoian or Iowan(?) ice sheet, and Benson (1952, p. 180) suggests that it is pre-Wisconsin, probably Illinoian age, although he states that this age determination is based on scanty and inconclusive evidence. The writers of this report believe, however, that the diversion channel system postdates the Missouri River trench, herein considered to be of Illinoian age. Flint (1949, p. 70) has pointed out that once an ice-diverted stream was established along a new course, it would quickly become incised below any prediversion divides farther west, so that the Missouri River should lie at or west of the drift border of the ice sheet that gave it birth. If this is true, then the limit of Illinoian glaciation in North Dakota would have been about the position of the Missouri trench, and the system of diversion channels would be a different age. Because no Nebraskan or Kansan deposits are recognized in this part of North Dakota and because the channel system is only slightly dissected by erosion, presumably the channel system is the result of a younger glacier. As the Iowan glacier was the most extensive, then the channel system is probably a result of that glacier. It is unlikely that the channel system and the Missouri River trench are contemporaneous in age as suggested by Benson (1952, p. 180). Even if the Illinoian glacier had extended west of the present Missouri River trench and remained stationary long enough to allow an extensive system of channels to form, it is very unlikely that the channel system would have been abandoned and a new system cut farther east to form the Missouri River trench. If, however, the trench was in existence but buried by ice when the channel system was cut, then the Missouri River drainage would relocate itself along the trench after retreat of the ice sheet. The southern end of the channel system joins the Missouri trench near Fort Yates, and this may indicate that the trench was in existence before the channel system was formed.

After the short Peorian interglacial interval the Tazewell glacier invaded this part of North Dakota, but its advance was probably halted before it had spread to the outer limits of the Iowan drift. In the Square Buttes coal field the deposits of the Tazewell glacier are not discernible from those of the Iowan. Upon withdrawal of the Tazewell ice sheet this part of North Dakota probably remained beyond the limit of glaciation for some time, for deposits of the Cary ice sheet have not been recognized in this area.

The Mankato ice sheet invaded central North Dakota and pushed west of the Missouri River. In the Square Buttes coal field the ice sheet split into two lobes, one advanced southward into the western part of the field to a line extending southeastward across the south-

west corner of T. 142 N., R. 87 W., the northern part of T. 141 N., R. 87 W., and into the northern and eastern parts of T. 141 N., R. 86 W. Melt water flowed through a series of diversion channels to the south and east across the Knife River–Heart River divide into Hailstone and Sweetbriar Creeks, and the creek valleys and diversion channels were filled with outwash debris. As this lobe of ice retreated northward, melt water cut new channels and discharged to the south and east into Sweetbriar and Square Butte Creeks and to the west toward the Knife River.

The other lobe of the Mankato ice sheet covered all of eastern and much of central Oliver County; melt water flowed southward along the western margin of this lobe, spilled across the stream divides, and discharged into the large tributary of Sweetbriar Creek in T. 141 N., R. 85 W. Apparently this lobe of ice retreated rather rapidly to a position north of Square Butte Creek, for no system of diversion channels exists south of the creek. The ice halted north of the high divide between Square Butte Creek and the Missouri and Knife Rivers; melt water ponded against the divide, spilled over, and discharged down deep channels into Square Butte Creek.

As the ice mass gradually melted back, preexisting drainage channels, such as Shark Creek, were uncovered and served as spillways for the melt water. With the retreat of the Mankota ice to the north and east of the Missouri trench, the river and its tributary creeks began to scour out the outwash filling their valleys. Drainage in many of the diversion channels in this coal field was abandoned or was taken over by small underfit streams.

STRUCTURE

The Square Buttes coal field is on the southeast flank of the broad Williston structural basin whose center is in west-central North Dakota. The Tertiary strata in the field dip less than 1° to the north and northeast, and this local variation from the westward regional dip probably is the result of a synclinal depression alined with Missouri River valley in this part of the State. Minor flexures with less than 25 feet closure interrupt the gentle northward dip. Along the east side of the field the strata dip regularly towards the north; on the west side to the northeast; and in the central part the strata are warped into minor undulations. The maximum structural relief in the Square Buttes field is 150 feet.

The attitude of the strata in the Square Buttes field is shown in figure 2. The contour lines are drawn at 25-foot intervals on the base of the Hagel coal bed which is about 250 feet above the base of the Fort Union formation.

Most of the elevations used in preparing the structure contour map were determined on coal beds, supplemented by elevations on the

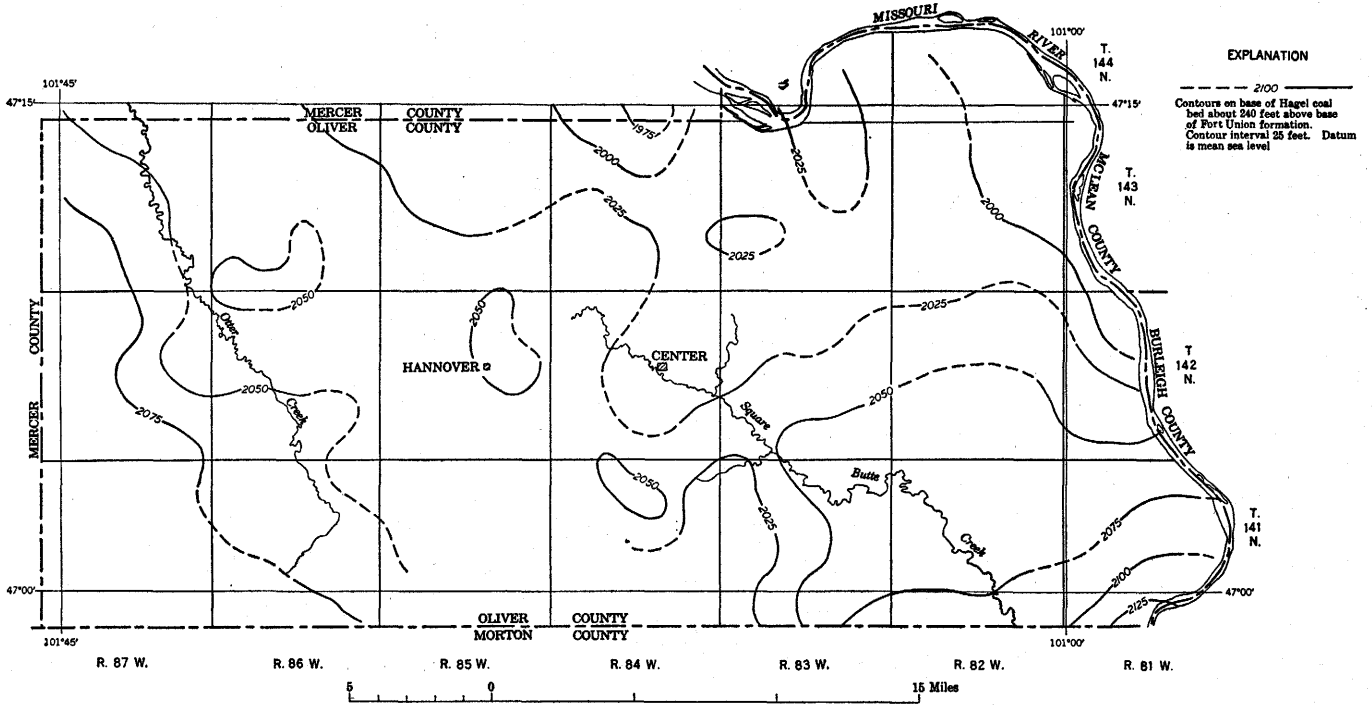

FIGURE 2.—Structure contour map of the Square Buttes coal field.

base of the Fort Union and Golden Valley formations. Little structural data could be obtained in most of the till-covered area or in the south-central and southwest parts of the coal field where coal outcrops are scarce. Because the scattered coal outcrops are difficult to correlate and the intervals between coal beds are not constant, errors may have been introduced when the structural readings were adjusted to the common datum plane.

ECONOMIC GEOLOGY

OIL AND GAS

Discovery of oil by the Amerada Petroleum Corp. in 1951 in the Clarence Iverson well No. 1 on the Nesson anticline, Williams County, N. Dak., started an intensive program of exploration in the Williston basin. Two exploratory wells drilled in the Square Buttes area showed no traces of oil or gas. Several test wells have also been drilled in surrounding areas without finding significant amounts of oil and gas. The Carter Oil Co. drilled the No. 1 Emma L. Semling well in the SE¼ SE¼ sec. 18, T. 141 N., R. 81 W., to a depth of 8,850 feet before it was plugged and abandoned in September 1942. In 1952 the Youngblood and Youngblood No. 1 Wachter well was drilled in the center of the SE¼ SW¼ sec. 3, T. 141 N., R. 81 W., about 3¼ miles northeast of the Carter test well. This well was plugged and abandoned at a depth of 7,841 feet in September 1952. The Tertiary strata in this area show no pronounced structural features that would encourage oil exploration, but the possibility of subsurface structures and stratigraphic traps in the Paleozoic rocks cannot be overlooked. Rocks of Mississippian, Devonian, and Ordovician age, from which oil is produced to the west and northwest on the Nesson anticline, and on the Cedar Creek anticline in eastern Montana, are present in the subsurface of this area.

COAL

In the Square Buttes field the coal reserves are in beds of the Fort Union formation. The areal distribution of each bed is shown on the geologic map (pl. 1). The numbers along the outcrop lines indicate where the thickness of the coal bed was measured and refer to the coal sections given in the township descriptions and plotted on plates 4–7. Coal beds are scattered throughout the Fort Union formation, but the thickest and most extensive are from 210 to 285 feet above the base of the formation. The Red Butte bed, about 380 feet above the base of the Fort Union, underlies large areas at higher altitudes in the field. The approximate stratigraphic positions of the most extensive beds are shown in the generalized columnar sections (fig. 3).

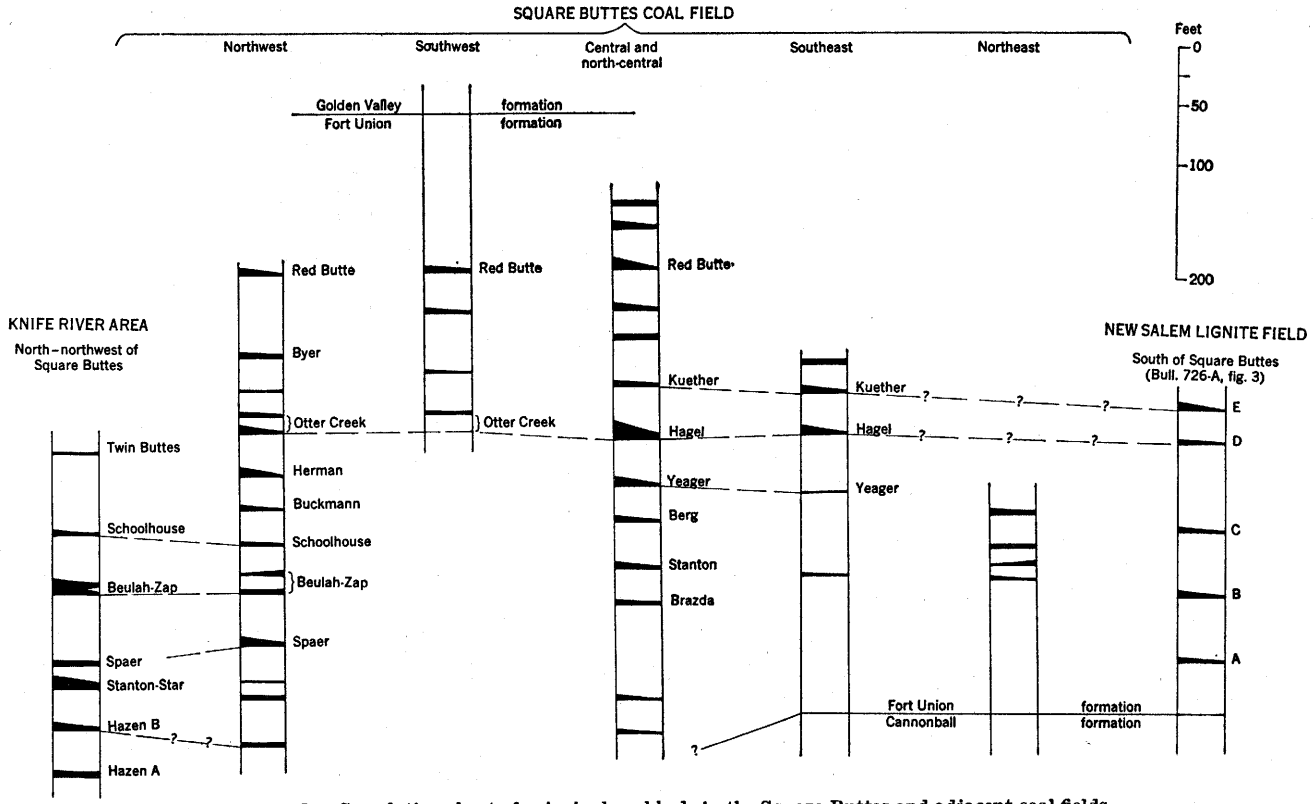

FIGURE 3.—Correlation chart of principal coal beds in the Square Buttes and adjacent coal fields.

Correlation of beds in the western part of the field with those in the central and north-central parts is difficult because of the broad Knife River–Square Butte Creek divide. The low, till-covered country along the north boundary of the coal field is also an effective barrier to the direct tracing and correlating of the beds in the Knife River drainage basin with those to the east in the rough country along Alderin Creek in Tps. 143 and 144 N., R. 84 W. Because the Red Butte bed is the only thick coal that could be traced accurately across the Knife River–Square Butte Creek divide, different names were applied to the other coal beds on either side of the divide. The Hagel bed seems to correlate with the Otter Creek bed. Many beds below the Hagel in the central and north-central parts of the field appear on figure 3 to be roughly equivalent to beds below the Otter Creek bed in the northwestern part of the area; but, because these beds crop out in widely separate areas, the true relation is unknown.

The correlation of beds in the Square Buttes coal field with those in the adjoining Knife River area and New Salem lignite field is shown also on figure 3. The Spaer, Stanton, Beulah-Zap, and Schoolhouse beds were traced directly into the Square Buttes field from the Knife River area. The bed 85 to 90 feet below the Spaer is correlated tentatively with the Hazen B bed of the Knife River area on the basis of its interval below the Beulah-Zap. No bed in this area can be correlated definitely with the Twin Buttes bed of the Knife River area.

The Stanton bed in the northern part of this coal field presents a major problem in correlation. The writers of this report believe that the Stanton and Beulah-Zap beds probably are equivalent, but Benson (1952, p. 255, 256) correlates the Stanton with the Star bed, which is 75 to 95 feet below the Beulah-Zap. In both the Knife River and Square Buttes areas the Beulah-Zap and Stanton beds crop out in different areas (see fig. 4), and no direct measurement of the interval between the two beds could be made in either area. The Star bed is restricted to the Knife River area and is present only within the area of outcrop of the Beulah-Zap bed. The tentative correlation of the Beulah-Zap and Stanton beds in the Square Buttes field is based on the similar stratigraphic interval of those two beds below the Red Butte bed and on their tenuous correlation by aneroid barometer between their areas of outcrop.

The *C* bed of the New Salem lignite field was traced northward into sec. 31, T. 141 N., R. 82 W., where it correlates with an unmappable coal about 230 feet above the base of the Fort Union formation. Because the *C* bed is only 155 feet above the base of the Fort Union and the overlying *D* bed is 230 feet above (Hancock, 1921, p. 13), it is thought that the *C* and *D* beds have been miscorrelated

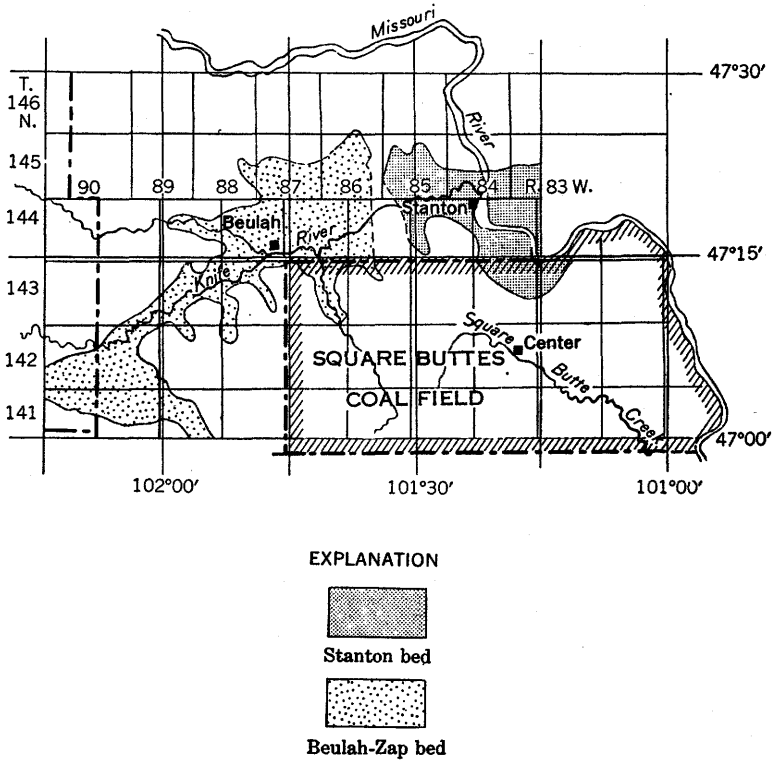

FIGURE 4.—Sketch map showing areas of outcrop of the Stanton and Beulah-Zap beds in the Knife River area and Square Buttes coal field.

in the northern part of the New Salem field, as a result the *D* bed rather than the *C* bed extends into the Square Buttes area. Based only on their intervals above the base of the Fort Union formation, the *D* and *E* beds of the New Salem field apparently are equivalent to the Hagel and Kuether beds, respectively, of the Square Buttes field.

COAL BEDS IN THE EASTERN AND CENTRAL AREAS

Local beds above the base of the Fort Union formation.—A zone of coal from 40 to 60 feet above the base of the Fort Union formation crops out on the west side of T. 142 N., R. 81 W., and the east side of T. 142 N., R. 82 W. This zone probably consists of several beds, each containing 3 to 4 feet of shaly coal.

Three thin beds, comprising a zone of coal about 32 feet thick and 115 feet above the base of the Fort Union formation, crop out over a very limited area in secs. 11 and 12, T. 143 N., R. 82 W. Only in a few places are these beds of mappable thickness.

A local bed 170 feet above the base of the Fort Union is present in the north-central part of T. 143 N., R. 82 W. The bed contains from 3 feet 4 inches to 5 feet of clean, hard lignite.

Local beds below the Brazda.—A local bed 110 feet below the Brazda bed was mapped along Mandan Lake Creek and for a short distance in the Missouri valley in Tps. 143 and 144 N., R. 83 W. Where mappable, the coal is 2 feet 1 inch to 4 feet 4 inches thick.

A local bed 80 feet below the Brazda bed crops out in the deep stream valleys in the northern part of T. 143 N., R. 83 W., and in a small part of sec. 35, T. 144 N., R. 83 W. This lenticular coal bed is of mappable thickness at only a few places along its outcrop. In the northwest quarter of T. 143 N., R. 83 W., the bed is composed of two coals, which are separated by 4 to 5 feet of sandy shale. The upper coal is unmappable; the lower has a maximum thickness of 3 feet. Along the valley of Mandan Lake Creek the bed consists of 2 feet 2 inches to 3 feet 11 inches of lignite.

Brazda bed.—The Brazda bed crops out in the rough country of the north-central part of the coal field. This bed, from 20 to 45 feet below the Stanton bed, is generally less than 2 feet thick along the northern edge of T. 143 N., R. 84 W., but thickens toward the south in that edge of the township. The only exposure of this coal along Mandan Lake Creek shows a thickness of 2 feet 4 inches. On the west side of T. 143 N., R. 83 W., the bed is 2 feet 5 inches and 3 feet 6 inches thick at localities 157 and 156, respectively. In the southeast corner of sec. 1, T. 143 N., R. 84 W., the Brazda coal is only 1 foot 8 inches thick, but it becomes thicker to the south and west along its outcrop and reaches a maximum measured thickness of 3 feet 2 inches at locality 104 in sec. 13, T. 143 N., R. 84 W. At locality 101 in sec. 4 of the same township the bed is split into two thin coals by a carbonaceous shale parting 3 feet 2 inches thick. The Brazda could not be traced northward as a mappable coal bed into the Knife River area. The northernmost exposure of the bed contains only 1 foot 7 inches of coal.

Stanton bed.—The Stanton bed, the southward continuation of a bed of the same name in the Knife River area, is burned and clinkered along most of its outcrop in the southern part of T. 144 N., R. 84 W., and in the northwest quarter of T. 143 N., R. 84 W. Measured sections in those areas show that the coal is from 2 feet 1 inch to 3 feet 11 inches thick. In the Knife River area south of Stanton the coal is 8 to 11 feet thick (Benson, 1952, p. 256). The outcrop of the Stanton bed was traced eastward across T. 143 N., R. 84 W., and into the western part of T. 143 N., R. 83 W. East of sec. 9, of the latter township, the bed is concealed by till. The maximum thickness of

the Stanton coal determined in this field is 4 feet 1 inch at locality 160, in sec. 17, T. 143 N., R. 83 W.

Local bed above the Stanton.—The clinker of a local bed 20 to 25 feet above the Stanton bed crops out in the southern part of T. 144 N., R. 84 W., and at a few places along the northern boundary of the adjacent township. At many places the clinker of this bed merges into that of the underlying Stanton bed, and the horizon of the clinker is difficult to recognize. This local bed contains 1 foot 10 inches of coal at the only place where it was measured, locality 99.

Berg bed.—The Berg bed which is 40 feet above the Stanton bed, is present in T. 143 N., R. 84 W., in the southern part of the SW¼ of T. 144 N., R. 84 W., and in a very small area along Alderin Creek in T. 143 N., R. 85 W. Apparently this bed does not extend northward into the Knife River area. The Berg is clinkered at many points along its outcrop in the northwest quarter of T. 143 N., R. 84 W. In sec. 7 of that township, at locality 115, an incomplete section of the bed shows 6 feet 6 inches of coal. Along the outcrop to the south and east the coal is from 3 feet 4 inches to 4 feet thick. In sec. 9, the bed contains only 1 foot 6 inches of coal. The outcrop of the Berg bed could not be traced eastward from sec. 15, T. 143 N., R. 84 W.

Yeager bed.—The Yeager bed, named for the Yeager mine in sec. 21, T. 143 N., R. 84 W., where the coal formerly was mined commercially, crops out along the valley of Square Butte Creek, in the north-central part of the area, and along either side of a large tributary of Square Butte Creek in T. 141 N., R. 83 W. In their common areas of outcrop in Tps. 143 and 144 N., R. 84 W., the Yeager bed is about 30 feet above the Berg bed. The stratigraphic interval between the Yeager and the overlying Hagel bed varies throughout the coal field. In the north-central area the Hagel is 25 to 40 feet above the Yeager; along Square Butte Creek the two beds are about 30 feet apart; and in the south-central part of T. 141 N., R. 83 W., the interval is 50 feet.

The maximum thickness of the Yeager bed was found in the Yeager mine. There, the bed is composed of two members separated by 8 feet 5 inches of sandy shale. The upper member is 5 feet 2 inches thick including two thin shale partings, and the lower contains 6 feet of clean coal. North of the Yeager mine the bed thins; along the north edge of the coal field in T. 144 N., R. 84 W., only 1 foot 10 inches of coal was found. The Yeager bed was traced eastward from the Yeager mine into the western part of T. 143 N., R. 83 W. At locality 165 in sec. 17, the bed is divided into two members 13 feet 4 inches apart. The upper and lower members are 2 feet 3 inches and 2 feet

2 inches thick, respectively. A short distance to the north and east the outcrop of the Yeager bed is concealed by till. In the valley of Square Butte Creek along the township line between T. 142 N., Rs. 83 and 84 W., the Yeager bed is 7 to 9 feet thick. The bed thins very rapidly towards the southeast; at the southeast corner of sec. 31, T. 142 N., R. 83 W., the Yeager coal is only 1 foot 7 inches thick. Numerous small mines mark the horizon of this bed in T. 141 N., R. 83 W., where the coal has a maximum measured thickness of only 1 foot 9 inches.

Local bed below the Hagel.—A local bed 120 feet below the Hagel bed crops out along Square Butte Creek and along a large tributary of the creek in the northeast quarter of T. 141 N., R. 83 W. Where mappable, the coal is from 2 feet to 2 feet 2 inches thick.

Hagel bed.—The Hagel bed, named for the Hagel mine in sec. 2, T. 141 N., R. 84 W., is the thickest bed and contains the greatest reserves of coal in the field. The Hagel is correlated with the Otter Creek bed which crops out in the western part of the coal field. In the north-central part of the field the outcrop of the Hagel bed is confined mainly to the west half of T. 143 N., R. 83 W., and to the southeast quarter of T. 143 N., R. 84 W. The thickest section of the Hagel coal in this general area was measured in a drill hole, locality 166d, in sec. 30, T. 143 N., R. 83 W. There, the bed is 7 feet thick including a 4-inch shale parting near the middle. To the west of this locality small patches of clinker mark the horizon of the Hagel bed, but the coal is not exposed. The Hagel bed is extensive in central and south-central Oliver County along Square Butte Creek and its tributaries. Masses of clinker are found along its outcrop at many points throughout the area. The Hagel coal is thickest on Square Butte Creek northwest of Center; in the mine just west of the cemetery in sec. 15, T. 142 N., R. 84 W., the bed is 18 feet 11 inches thick, including 5 thin partings in the upper one-half of the bed. Along the large tributary of Square Butte Creek in T. 141 N., R. 84 W., the Hagel coal ranges in thickness from 7 feet 5 inches to 10 feet 6 inches. Eastward from that township the coal thins rapidly; in the north-central part of T. 141 N., R. 83 W., the Hagel contains less than 2 feet of coal. On the north side of Square Butte Creek the Hagel bed was traced as far eastward as sec. 22, T. 142 N., R. 83 W. The coal is reported to be about 6 feet thick along its outcrop in T. 142 N., R. 83 W.

Local beds above the Hagel.—Coal in a zone 90 and 110 feet above the Hagel bed is present in the southwest quarter of T. 143 N., R. 83 W., and in secs. 5 and 6, T. 142 N., R. 83 W. This zone contains several thin, discontinuous beds that are locally of mappable thickness. The basal bed in this zone is 2 feet 2 inches thick at locality 169 in sec. 19, T. 143 N., R. 83 W., but less than half a mile south the

coal is only 1 foot 10 inches thick. Small abandoned mines in secs. 21, 28, and 32, T. 143 N., R. 83 W., and in sec. 5 of the township to the south, mark the horizons of other thin beds higher in the coal zone.

A local bed 150 feet above the Hagel bed underlies parts of the high divide in the northwest quarter of T. 142 N., R. 83 W. The only measured section shows 2 feet 7 inches of coal having a 1-foot carbonaceous shale parting in the lower part of the bed.

Local beds below the Kuether.—A thin coal 50 feet below a bed questionably correlated with the Kuether bed crops out in two small areas in the eastern part of the coal field. The bed was mapped for a short distance on either side of Sherk Creek in the northern part of T. 142 N., R. 82 W., where it is 3 feet thick. A bed at the same stratigraphic position crops out in a small area along the boundary between Tps. 141 and 142 N., R. 82 W. The coal is 2 feet 5 inches thick at locality 185 in sec. 32, T. 142 N., R. 82 W., but within a mile it thins to less than 2 feet.

A local bed 25 feet below a bed questionably correlated with the Kuether underlies a small area in secs. 2 and 3, T. 142 N., R. 82 W. The bed contains 2 feet 7 inches of clean coal.

Kuether bed.—The Kuether bed, which is 35 to 45 feet above the Hagel, was named for the Kuether mine in sec. 23, T. 141 N., R. 84 W. The Kuether is a fairly persistant horizon in central and south-central Oliver County. The Kuether coal is thickest along the large stream valleys in the northern and eastern parts of T. 141 N., R. 84 W. At localities 144 and 146 partial exposures of the bed reveal 8 feet 8 inches of coal broken by a thin parting 7 feet below the top of the bed. At other places in that township thick partings of shale and clay split the Kuether into several thin beds. The coal thins to the east, and in the adjoining township it ranges in thickness from 2 feet 6 inches to 5 feet 9 inches. The Kuether bed could not be traced accurately to the southeast beyond sec. 28, T. 141 N., R. 83 W. The horizon of the Kuether bed is difficult to map along Square Butte Creek, especially on the north side. South of Center the coal is reported to be about 8 feet thick, but the maximum measured thickness is 5 feet 6 inches. Northwest of Center the bed contains only about 2 feet of coal in the northwest corner of T. 142 N., R. 84 W. Outcrops of a bed questionably correlated with the Kuether occur in the southeast corner of T. 142 N., R. 83 W., and to the east in T. 142 N., R. 82 W. Incomplete sections of the bed show 2 feet 3 inches to 4 feet 1 inch of coal.

Local bed above the Kuether.—A local bed 25 feet above the Kuether bed underlies parts of secs. 28, 29, 32, and 33, T. 141 N., R. 83 W. A partial exposure of the bed in an old mine in sec. 33 reveals 4 feet 2 inches of coal.

Local beds below the Red Butte.—A coal bed 60 to 65 feet below the Red Butte bed crops out for a short distance along Square Butte Creek in secs. 2, 3, 10, and 11, T. 142 N., R. 85 W. On the north side of the creek the coal is 2 feet thick, but on the south only 1 foot 8 inches. Coal at the same stratigraphic position is present in the northwest quarter of the township to the west. The bed formerly was mined in sec. 7, T. 143 N., R. 85 W., where the coal is 4 feet thick.

A local bed 35 feet below the Red Butte bed crops out in two widely separated areas of this coal field. The bed contains from 4 feet 10 inches to 6 feet of coal in small areas of secs. 7, 17, and 18, T. 143 N., R. 85 W., and of secs. 12 and 13, T. 143 N., R. 86 W. In T. 141 N., R. 85 W., this coal is 3 to 5 feet thick.

Red Butte bed.—The Red Butte bed, named for its presence beneath Red Butte, underlies the broad Knife River–Square Butte Creek divide in the western part of the coal field. To the west it crops out on either side of the Otter Creek–Brady Creek divide. Outcrops of the Red Butte bed were mapped along the large tributary of Sweetbriar Creek in T. 141 N., R. 85 W., and high on the north side of the Missouri River–Square Butte Creek divide in T. 143 N., R. 84 W. The Red Butte bed was the only coal bed that could be traced accurately through the divide between the Knife River and Square Butte Creek drainage basins. The reserves in the Red Butte bed are surpassed only by the reserves in the Hagel and Otter Creek beds.

The greatest measured thickness of the Red Butte coal is at locality 86d at the corner of secs. 9, 10, 15, and 16, T. 142 N., R. 85 W. There, the coal is 10 feet 6 inches thick, with a 6-inch shale parting in the lower part of the bed. In a mine about one-quarter of a mile to the east the bed is split by 12 feet of sandstone and shale into two coals 2 feet 4 inches and 3 feet 9 inches thick. South of Hannover the measured sections show only 1 foot 5 inches to 2 feet 8 inches of coal. In T. 143 N., R 85 W., the coal ranges in thickness from 5 feet in the southwest corner to 8 feet 1 inch at the old underground mine in sec. 18. To the west, in the valley of Brady Creek, the Red Butte coal has a maximum measured thickness of 5 feet. The only exposure of the bed on the west side of the Otter Creek–Brady Creek divide is at locality 52, in sec. 33, T. 143 N., R. 86 W.; there, the lower part of the bed is covered and only 3 feet of workable coal could be measured. The horizon of the Red Butte bed could not be recognized east of Otter Creek in the west-central part of the coal field, except in a small area of secs. 24 and 25, T. 142 N., R. 86 W., and secs. 30 and 31, T. 142 N., R. 85 W., where the coal is 2 feet 4 inches thick. The Red Butte bed was mapped through most of the area north of the large tributary of Sweetbrier Creek in T. 141 N., R. 85 W., and for a short distance on the south side of that tributary. A power

auger drilled through 5 feet of coal in the bed in sec. 8. Small clinkers mark the outcrop of the Red Butte bed on the north side of the Missouri River–Square Butte Creek divide in the southeast quarter of T. 143 N., R. 84 W. A hole drilled in sec. 35 penetrated 5 feet of coal that is split by two thin partings.

Local beds above the Red Butte.—A local bed 35 feet above the Red Butte bed is present on some of the high divides. In the southern part of T. 143 N., R. 85 W., the coal ranges in thickness from 3 feet to 4 feet 11 inches, but is of small areal extent. The bed is clinkered at several points on the east side of T. 142 N., R. 85 W., and the west side of T. 142 N., R. 84 W. In sec. 31 of the latter township the coal is 3 feet 3 inches thick. This bed is less than 2 feet thick in secs. 20 and 21, T. 141 N., R. 85 W. This local bed contains 3 feet of coal on the high ridges in the southeast corner of T. 143 N., R. 84 W., and in secs. 1 and 2 of the township to the south.

A 2-foot 6-inch coal bed, about 55 feet above the Red Butte bed, underlies a small area in secs. 21 and 28, T. 142 N., R. 85 W.

COAL BEDS IN THE WESTERN AREA

Local beds below the Spaer.—A bed 85 to 90 feet below the Spaer bed crops out in sec. 32, T. 144 N., R. 87 W., where it contains 4 feet 5 inches of weathered coal. This bed is questionably correlated with the Hazen B bed in the Knife River area.

A bed consisting of two members 15 feet apart and lying 45 to 50 feet below the Spaer bed crops out along the lower valley of Otter Creek and along a small stream in the northwest corner of the coal field. At locality 2, the exposure shows from the base upward 3 feet 10 inches of coal, 15 feet of shale, and 1 foot of coal. The 3 feet 1 inch of coal exposed in sec. 5, T. 143 N., R. 87 W., probably is in the lower member.

Spaer bed.—The Spaer bed, which is correlated with a bed of the same name in the Knife River area and which lies 45 feet below the Beulah-Zap bed, crops out on Otter Creek and along the south boundary of T. 144 N., R. 87 W., on the rolling upland south of the Knife River valley. The greatest thickness of the Spaer bed is at locality 5 in sec. 22, T. 143 N., R. 87 W., where the coal is 7 feet 1 inch thick and has only a 4½-inch parting. North of that locality the bed thins and the partings increase in abundance and thickness; at locality 4, sec. 10, it contains 5 feet 8¼ inches of coal with more than 1 foot of clay partings. The Spaer is only 3 feet 10¼ inches thick at the north edge of T. 143 N., R. 87 W., and does not contain workable coal.

Beulah-Zap bed.—The Beulah-Zap bed, which is correlated with the Beulah-Zap bed of the Knife River area, is found on both sides

of Otter Creek in Tps. 143 and 144 N., R. 87 W., and along Brady Creek and its tributaries in the NW¼ T. 143 N., R. 86 W. The Beulah-Zap bed was not recognized east of Brady Creek. In the northwest corner of the coal field, the Beulah-Zap is composed of two beds about 15 feet apart. At locality 7, in sec. 5, T. 143 N., R. 87 W., the lower and upper coals are 4 feet and 1 foot thick, respectively. South and east of that section the split in the Beulah-Zap bed was recognized at only a few places. All outcrops in the valley of Otter Creek were correlated with the upper bed, which has a maximum measured thickness of 2 feet 7¼ inches in an abandoned mine in sec. 26, T. 143 N., R. 87 W. The split in the Beulah-Zap was recognized along Brady Creek where the only exposure of the lower bed shows 4 feet of coal and the upper bed ranges in thickness from 3 feet 4 inches to 3 feet 7 inches.

Schoolhouse bed.—A thin, discontinuous bed that crops out in the northwest part of T. 143 N., R. 87 W., was correlated with the Schoolhouse bed of the Knife River area. Where measured, the coal is 1 foot 8½ inches to 3 feet thick. This bed lies 30 to 45 feet above the Beulah-Zap.

Buckmann bed.—The Buckmann bed, named for its occurrence on the Buckmann farm in sec. 34, T. 143 N., R. 87 W., is exposed in the valley of Otter Creek in T. 143 N., R. 87 W., on the extreme west side of T. 143 N., R. 86 W., in the northwest corner of T. 142 N., R. 86 W., and in the northeast corner of T. 142 N., R. 87 W. The bed ranges in thickness from 4 feet 5½ inches at locality 17 in sec. 21, T. 143 N., R. 87 W., to 1 foot 9 inches at locality 19 in sec. 33 of the same township. Where the Buckmann bed passes below the level of Otter Creek in sec. 7, T. 142 N., R. 86 W., the coal is 2 feet 5 inches thick and has a 2-inch parting. This bed was not traced westward into the Knife River area. The Buckmann lies 65 to 75 feet above the Beulah-Zap bed.

Herman bed.—The Herman bed was named for its outcrop on the Herman farm in sec. 28, T. 143 N., R. 87 W. This bed was mapped only on the west side of Otter Creek in Tps. 142 and 143 N., R. 87 W., because east of the creek the coal is only 11 inches thick. The thickest section of the Herman bed was measured at locality 21 in sec. 31, T. 143 N., R. 87 W. There, the upper 10 feet 6 inches of the bed is exposed, but it contains only 4 feet 10 inches of workable coal. North of that locality the mantle of till made it impossible to trace the Herman bed for more than a short distance. At other outcrops in T. 143 N., R. 87 W., the Herman contains 3 feet 2 inches to 4 feet 7½ inches of coal. To the south, in T. 142 N., R. 86 W., the coal ranges in thickness from 1 foot 8 inches at locality 25 in sec. 10 to

4 feet 2 inches at locality 27 in sec. 14. The Herman is 25 to 30 feet above the Buckmann bed.

Otter Creek bed.—The Otter Creek bed, so named because of its outcrop along Otter Creek, lies 135 to 145 feet above the Beulah-Zap bed. As discussed previously, the Otter Creek bed seems to correlate with the Hagel bed in the central part of the field. The Otter Creek bed consists of two coals separated by an 11- to 17-foot parting but rarely are both coals of mappable thickness at the same place. This bed is persistent in the west-central part of the coal field, but a small abandoned mine in sec. 33 is the only indication of it on the west side of Otter Creek in T. 143 N., R. 87 W. To the south the bed crops out conspicuously along the large tributary of Otter Creek that flows northward across the east side of T. 142 N., R. 87 W. Along that tributary the upper coal is 1 foot to 3 feet 8 inches thick and the lower coal 3 to 4 feet thick. In the valley of Brush Creek on the west edge of the coal field an incomplete exposure of the upper member at locality 28, sec. 7, T. 142 N., R. 87 W., shows 3 feet of weathered coal.

The outcrop of this bed was mapped along Otter Creek as far south as sec. 3, T. 141 N., R. 86 W. The lower member passes beneath the alluvium of the creek at the south boundary of T. 142 N., R. 86 W.; consequently, from there southward the bed was mapped on the outcrop of the upper member. Coal sections, measured on the bed in Tps. 141 and 142 N., R. 86 W., show that the upper coal is 11 inches to 4 feet 6 inches thick and the lower 1 foot 9 inches to 3 feet 8½ inches thick. A shale parting 16 feet 9 inches thick separates the two members at locality 61 near the north edge of T. 142 N., R. 86 W. The cover of till on the rolling country east of Otter Creek prevented the mapping of the Otter Creek bed north of sec. 7, T. 143 N., R. 86 W. At locality 51, in sec. 19 of that township, 2 feet 4 inches of the upper member is exposed below glacial till; about a mile to the north at locality 50 the lower member, which contains 3 feet 3 inches of clean coal, is being mined. Because it is about 135 feet above the Beulah-Zap bed, the thick bed in the northeast quarter of T. 143 N., R. 86 W., and southeastern part of T. 144 N., R. 86 W., was correlated with the Otter Creek bed. In that area no split was recognized in this bed which contains 7 feet of clean coal in the old underground mine in sec. 35, T. 144 N., R. 86 W. This is the only known exposure of the Otter Creek bed east of Otter Creek valley.

Local beds above the Otter Creek.—A coal seam 2 feet 6 inches thick was found 35 feet above the Otter Creek bed in secs. 9 and 14, T. 142 N., R. 87 W., but it could be traced only for a short distance.

Outcrops of a bed 45 to 50 feet above the base of the Otter Creek were found in the northern part of T. 141 N., R. 86 W., and in sec.

32, T. 142 N., R. 86 W. The thickest part of the bed exposed is in the large abandoned mine in the SE¼ sec. 3, T. 141 N., R. 86 W. There, the bed is composed of two coals separated by 4 feet 11 inches of inter bedded shale and coal. The upper coal is 3 feet 7 inches thick; only 1 foot of the lower coal is exposed. In sec. 5 of the same township this bed contains only 1 foot 4 inches of workable coal.

A bed, 55 to 70 feet above the Otter Creek, crops out in the central and southeastern parts of T. 142 N., R. 87 W., and along the large stream in the northeast corner of T. 141 N., R. 87 W. This bed may be the lateral equivalent of the bed 45 to 50 feet above the Otter Creek bed, which crops out to the east along Otter Creek. However, they were mapped separately, because the outcrops of the two beds are far apart and there is a difference of 20 feet in their interval above th Otter Creek bed. This local bed ranges in thickness from 2 feet 4 inches to 4 feet 9 inches.

Several mines have been worked on a coal seam 100 feet above the Otter Creek bed along Otter and Sweetbrier Creeks in T. 141 N., R. 86 W. Measured sections show that the coal is 2 feet 3 inches to 3 feet 10 inches thick.

A thin seam 205 to 210 feet above the Otter Creek bed crops out in the southwest corner of the coal field where, in sec. 31, T. 14 N., R. 87 W., a power auger drilled through 1 foot 10 inches of coal at an old mine.

Byer bed.—The Byer bed, 65 feet above the Otter Creek bed, crops out on the east side of Otter Creek in the central and southwestern parts of T. 143 N., R. 86 W., and in the central and northwestern parts of T. 142 N., R. 86 W. This bed has a maximum thickness of 3 feet 10 inches at an abandoned mine, locality 62d, in sec. 8, T. 142 N., R. 86 W. Several beds in the western part of the coal field may be at approximately the same horizon, but because the outcrops are so widely separated, no attempt was made to correlate them with the Byer bed.

PHYSICAL AND CHEMICAL PROPERTIES

Eight coal samples, collected from beds of the Fort Union formation in the Square Buttes coal field, were analyzed (see table 1) by the U. S. Bureau of Mines. The coal in the Square Buttes area is of lignite rank; it contains 48 to 53 percent fixed carbon and has a heating value on a moist matter-free basis of 6,400 to 7,600 Btu. The lignite is a tough brownish-black coal with a woody texture. The moisture content of the coal in this area ranges from about 35 to 40 percent, and the coal readily slacks when dried.

Seven samples of lignite from 6 coal beds in the western part of the field were analyzed in Washington by the Geological Survey for uranium and other metals. The analyses showed insignificant amounts

TABLE 1.—*Analyses of coal from the Square Buttes coal field, Oliver and Mercer Counties, N. Dak.*

Source	Laboratory No. of sample	Air-dry loss	Form of analysis [1]	Proximate				Ultimate					Heating value (Btu)	Classification [2] [3]
				Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen		
Hagel mine (north strip pit), NW¼ sec. 2, T. 141 N., R. 84 W.; Hagel bed.	D-80824	-------	A	35.7	27.5	30.4	6.4	0.6	6.8	41.5	0.7	44.0	7,010	Lignite (53–66)
			B	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	
			C	-------	42.8	47.3	9.9	.9	4.3	64.6	1.1	19.2	10,910	
			D	-------	47.5	52.5	-------	1.0	4.8	71.7	1.2	21.3	12,110	
Schmidt mine, NE¼ sec. 13. T. 142 N., R. 84 W.; Hagel bed.	D-80825	-------	A	34.6	29.9	31.5	4.0	.4	6.9	43.1	.6	45.0	7,310	Lignite (52–76)
			B	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	
			C	-------	45.7	48.2	6.1	.7	4.6	65.9	.9	21.8	11,170	
			D	-------	48.6	51.4	-------	.7	4.9	70.2	1.0	23.2	11,900	
Schenk mine, NE¼ sec. 25, T. 142 N., R. 84 W.; Yeager bed.	D-80823	-------	A	36.2	28.3	31.3	4.2	.4	6.9	42.3	.7	45.5	7,140	Lignite (53–75)
			B	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	
			C	-------	44.3	49.1	6.6	.6	4.6	66.3	1.0	20.9	11,190	
			D	-------	47.4	52.6	-------	.6	4.9	71.0	1.1	22.4	11,980	
Strip pit, SE¼ sec. 9, T. 142 N., R. 87 W.; Otter Creek bed.	D-55179	32.2	A	39.5	26.5	28.9	5.1	.9	7.1	39.9	.6	46.4	6,740	Lignite (53–71)
			B	10.8	39.1	42.5	7.6	1.3	5.1	58.9	.9	26.2	9,940	
			C	-------	43.9	47.6	8.5	1.4	4.4	66.0	1.0	18.7	11,140	
			D	-------	48.0	52.0	-------	1.5	4.8	72.2	1.0	20.5	12,180	
Strip pit, SE¼ sec. 14, T. 142 N., R. 87 W.; Otter Creek bed.	D-55176	29.0	A	38.0	28.8	29.0	4.2	.5	6.9	40.4	.6	47.4	6,740	Lignite (51–71)
			B	12.8	40.6	40.7	5.9	.8	5.2	56.8	.9	30.4	9,490	
			C	-------	46.5	46.7	6.8	.9	4.3	65.1	1.0	21.9	10,880	
			D	-------	49.9	50.1	-------	.9	4.7	69.9	1.0	23.5	11,670	
Outcrop face, NE¼ sec. 14, T. 142 N., R. 87 W.; Herman bed.	D-55177	31.3	A	39.5	28.3	25.3	6.9	.4	6.8	36.2	.6	49.1	5,910	Lignite (48–64)
			B	11.9	41.2	36.8	10.1	.6	4.8	52.8	.9	30.8	8,610	
			C	-------	46.7	41.9	11.4	.6	4.0	59.9	1.0	23.1	9,770	
			D	-------	52.7	47.3	-------	.7	4.5	67.6	1.1	26.1	11,030	
Strip pit, SE¼ sec. 18, T. 143 N., R. 86 W.; Otter Creek bed.	D-55175	29.3	A	36.7	27.2	28.3	7.8	2.1	6.7	39.2	.6	43.6	6,670	Lignite (52–73)
			B	10.4	38.5	40.0	11.1	3.0	4.9	55.5	.8	24.7	9,430	
			C	-------	43.0	44.7	12.3	3.3	4.2	62.0	.9	17.3	10,520	
			D	-------	49.0	51.0	-------	3.8	4.7	70.7	1.0	19.8	12,000	
Strip pit, NW¼ sec. 33, T. 143 N., R. 86 W.; Red Butte bed.	D-55178	33.3	A	41.0	25.9	28.9	4.2	.5	7.0	38.0	.6	49.7	6,290	Lignite (53–66)
			B	11.5	38.9	43.3	6.3	.8	4.9	57.0	.9	30.1	9,430	
			C	-------	43.9	49.0	7.1	.9	4.1	64.4	1.0	22.5	10,660	
			D	-------	47.3	52.7	-------	.9	4.4	69.4	1.0	24.3	11,480	

[1] A, as received; B, air dried; C, moisture free; D, moisture and ash free.
[2] American Society for Testing Materials, standard specifications for classification of coals by rank, designation D 388–38, 1938.
[3] Numbers in parentheses are on the mineral-matter-free basis. The first number represents fixed carbon on the dry basis reported to the nearest whole percent; the second number represents Btu on the moist basis calculated by the Parr formula and expressed as hundreds of Btu.

of uranium (table 2). The kind and amount of other metals in the coals are shown in table 3.

TABLE 2.—*Uranium content of coals in the Square Buttes coal field, North Dakota*

[Analysts, W. P. Tucker and B. A. McCall]

Coal bed and location of sample	Laboratory No.	Uranium [1] [2] (percent)	Ash (percent)	Uranium in ash (percent
Otter Creek bed, SW¼ sec. 14, T. 142 N., R. 87 W.	49874	0.0001	5.93	0.0023
Red Butte bed, NW¼ sec. 33, T. 143 N., R. 86 W.	49875	.0001	4.59	.0021
Beulah-Zap bed, NE¼ sec. 9, T. 143 N., R. 86 W.	49876	.0003	10.24	.0030
Local bed 100 feet above Otter Creek bed, NW¼ sec. 35, T. 141 N., R. 86 W.	49877	.0001	8.50	.0011
Local bed 45–50 feet above Otter Creek bed, SE¼ sec. 3, T. 141 N., R. 86 W.	49878	.0007	17.33	.004
Herman bed, NE¼ sec. 14, T. 142 N., R. 87 W.	49879	.0001	7.16	.0019
Otter Creek bed, SE¼ sec. 9, T. 142 N., R. 87 W.	49880	.0001	12.86	.0010

[1] Analysis of sample dried at 110° C. to constant weight.
[2] The equivalent uranium content of each sample is less than 0.001 percent.

TABLE 3.—*Quantitative spectrochemical determinations of elements* [1] *in the ash of coals in the Square Buttes coal field, North Dakota*

[Analyst, A. A. Chodos. In percent of ash]

Laboratory No. of sample	Ge	Ga	V	Cu	Cr	Zn	Ni	Co	Be	Y	Li
49874	------	0.002	0.01	0.02	0.007	0.7	0.002	0.001	0.001	0.01	0.02
49875	------	.002	.005	.004	.002	.1	.005	.002	.0003	.01	.02
49876	------	.002	.008	.005	.006	------	.005	.002	.0002	.01	------
49877	------	.002	.007	.01	.01	.7	.02	.009	.0005	.03	.02
49878	------	.003	.01	.008	.006	.5	.02	.002	.0002	.01	.02
49879	0.002	.004	.02	.01	.01	.4	.002	.002	.005	.02	.02
49880	------	.002	.006	.004	.005	.06	.003	.001	.0007	------	------

[1] Molybdenum looked for but not found.

CLINKER

The large quantity of ground water associated with coal beds of the Fort Union formation is credited with restricting burning to such an extent that only in a few places are there masses of clinker. The reddish, bricklike masses, known also as scoria and porcellanite, were formed when heat from the burning coal baked and fused the overlying rocks. The burning is caused principally by spontaneous combustion, but lightning, prairie fires, and man occasionally ignite coal beds. Physical and chemical changes that take place during the formation of clinker are described in detail by Rogers (1917).

Clinker is abundant along outcrops of the Stanton, Berg, and Yeager beds in the NW¼ T. 143 N., R. 84 W., and the south edge of T. 144 N., R. 84 W. Small masses are found also on the Hagel bed in the Square Butte Creek valley from 1½ miles northwest of Center southeastward to the southwest corner of T. 142 N., R. 83 W. Somewhat larger masses on the Hagel are in sec. 36, T. 142 N., R. 84 W., and in sec. 1, T. 141 N., R. 84 W.

Fragments of clinker in the till of Wisconsin age indicate that some burning took place before that glacial stage—perhaps even as early as Tertiary time.

MINING

Open pit.—All the coal that is mined commercially in the Square Buttes coal field is from the Hagel mine, about 3 miles south of Center. Coal was dug from numerous small strip pits for many years, and several landowners continue to strip enough coal from open pits for their winter fuel. In 1949 six strip mines were in commercial production, but by 1952 only the Hagel coal mine remained in operation. Table 4 gives the information on the coal production in the Square Buttes coal field for the period 1949-52. The Hagel coal mine, the leading producer in Oliver County for the period 1949-51, supplied from 71 to 83 percent of the coal sold in the area. In 1952 the Hagel mine produced 6,280 tons of lignite from the Hagel bed, all for local use. The overburden is removed by a bulldozer, and the coal is mined with a power shovel. The coal is passed over a sizing screen before it is sold. The coal mined commercially in the Square Buttes field since 1949 has come from the Yeager, Hagel, and Kuether beds, which are 210 to 285 feet above the base of the Fort Union formation. In the Yeager and Schenk mines the coal was stripped from the Yeager bed; in the Hagel and Schmidt mines from the Hagel bed; and in the Kuether, Glenn-Burn, and Light mines from the Kuether bed.

TABLE 4.—*Coal production in the Square Buttes coal field, Oliver and Mercer Counties, N. Dak., 1949–52*

[Data from annual reports of Coal Mine Inspection Department, State of North Dakota]

Name and location of mine [1]	Production (tons)				
	1949	1950	1951	1952	Total
Hagel, NW¼ sec. 2, T. 141 N., R. 84 W.	4,775	5,656	6,920	6,280	23,631
Schmidt, NE¼ sec. 13, T. 142 N., R. 84 W.	920	975	560	0	2,455
Light, SW¼ sec. 22, T. 142 N., R. 84 W.	0	710	752	0	1,462
Kuether, NE¼ sec. 23, T. 141 N., R. 84 W.	200	280	125	0	605
Schenk, NE¼ sec. 25, T. 142 N., R. 84 W.	500	217	0	0	717
Yeager, SE¼ sec. 21, T. 143 N., R. 84 W.	92	100	0	0	192
Glenn-Burn, SW¼ sec. 23, T. 141 N., R. 84 W.	153	0	0	0	153
Total	6,640	7,938	8,357	6,280	29,215

[1] All mines are strip pits, and coal is for local use.

Underground.—Although most of the mining has been open pit, several underground mines formerly were in operation. In the large abandoned underground mine in sec. 35, T. 144 N., R. 86 W., the 7-foot Otter Creek bed was mined extensively by the room-and-pillar method. The drift mine in the 15-foot Hagel bed in the SW¼ sec. 15, T. 142 N., R. 84 W., just west of Center, was operated by the Superior

Coal Co. until the bed caught fire in March 1942. Holes drilled near the small abandoned drift mines on the Red Butte bed in the SE¼ sec. 18 and in the SE¼ sec. 31, T. 143 N., R. 85 W., disclosed 7½ feet and 5 feet of coal, respectively, in that bed. Coal was dug formerly from the Brazda bed in a small drift mine along Mandan Lake Creek in the NE¼ sec. 14, T. 143 N., R. 83 W.

MINING PROSPECTS

Although the Square Buttes coal field contains several areas that are possibly suitable for large-scale strip mining, the lack of transportation facilities probably will restrict exploitation for some time—except for local use. Most of the strippable areas are in the central and south-central parts of the coal field about 10 to 17 miles from the Northern Pacific Railway which operates along the Missouri River on the east and northeast edges of the field. Coal mined in this area also would have to compete with the strip mines in the Knife River area, which have good access to the railroad.

In this report only those coal beds 6 feet or more thick and within 60 feet of the land surface are considered suitable for strip mining. Location of possible prospects, most of which are in the Hagel bed, are shown by a pattern of ruled lines on the geologic map (pl. 1). In secs. 32 and 33, T. 143 N., R. 84 W., and in secs. 4, 5, 8, and 9, T. 142 N., R. 84 W., the alluvium in the valley of Square Butte Creek and the fill in the large diversion channel could be removed easily to expose the Hagel bed, which in that area consists of two coals, each more than 5 feet thick, separated by 4 feet 10 inches of thin coal and partings. The Hagel bed underlies a large area on the north side of Square Butte Creek in secs. 9, 10, 11, 14, and 15, T. 142 N., R. 84 W. Across the creek in the old Superior Coal Co. mine the Hagel coal is 15 feet thick, broken by a 2½-foot parting in the upper third of the bed. Another possible stripping area underlain by the Hagel bed is on the south side of Square Butte Creek in the southeast quarter of T. 142 N., R. 84 W., and in sec. 30, T. 142 N., R. 83 W. The Hagel could not be measured in that area, but it is probably 10 to 15 feet thick. To the south a large area surrounding the Hagel mine in sec. 2, T. 141 N., R. 84 W., might be suitable for large-scale stripping operations. In that mine the coal, 10 feet 6 inches thick, has only a 3-inch parting. West of the Hagel mine the Hagel coal has several partings, but a small area in secs. 3, 4, 9, and 10 might contain strippable coal.

Strip mining of the Kuether bed might be economically feasible in secs. 14, 22, 23, 24, and 26, T. 141 N., R. 84 W., near the Kuether and Glenn-Burn mines, where the coal is more than 8 feet 8 inches thick, with a solitary parting about 1 foot thick.

The Otter Creek bed has less than 40 feet of overburden along the south edge of T. 144 N., R. 86 W., and in secs. 1, 2, and 3, T. 143 N., R. 86 W.; it contains 7 feet of clean coal, part of which has been mined in underground workings.

COAL RESERVES

About 2,857,230,000 tons of coal is contained in beds more than 2½ feet thick and within 500 feet of the land surface in the Square Buttes field. The total given is a minimum rather than a maximum estimate of coal reserves in the field, because the reserves were calculated from thickness measurements on outcrops that have been subjected to slumping, slaking, and weathering. Samples obtained by drilling with a power auger reveal that the beds are thicker and more numerous than the surface exposures indicate. The reserves are reported in table 5 according to township, bed, class, and thickness; the measured reserves are reported with the indicated reserves, because only a few thickness measurements of coals were taken. Of the total reserves, 46.8 percent are in beds from 2½ to 5 feet thick; 27.5 percent in beds from 5 to 10 feet thick; and 25.7 percent are in beds more than 10 feet thick. The area also has about 320,720,000 tons of lignite in beds 1½ to 2½ feet thick, but this coal is not included in the table 5 estimates.

Coal reserves are given in table 6 by beds; about 64 percent of the total reserves are contained in four beds—the Hagel (993,810,000 tons), Otter Creek (312,680,000 tons), Red Butte (275,460,000 tons), and Kuether (251,110,000 tons). About 75 percent of the reserves are in eight townships in the west half of the area:

	Tons
T. 141 N., R. 84 W.	298, 540, 000
T. 142 N., R. 84 W.	693, 270, 000
T. 143 N., R. 84 W.	239, 130, 000
T. 142 N., R. 85 W.	156, 150, 000
T. 142 N., R. 86 W.	163, 730, 000
T. 143 N., R. 86 W.	163, 270, 000
T. 142 N., R. 87 W.	194, 520, 000
T. 143 N., R. 87 W.	249, 320, 000

Reserves in the categories—measured, indicated, and inferred—in each bed and each township were computed by setting arbitrary areal limits from a point of measurement of the coal; by measuring on the map the area underlain by each category with a planimeter, determining the weighted average thickness and assuming that the weight of 1 acre-foot of lignite is 1,750 short tons. Measured reserves were limited to areas not more than one-quarter of a mile from a point of measurement; indicated, to areas one-quarter to one-half a mile from the measured outcrop; and inferred, the areas beyond those of in-

TABLE 5.—*Estimated reserves of coal in the Square Buttes coal field, North Dakota*

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of the thickness shown—										
			Measured and indicated					Inferred					Total measured and indicated and inferred [1]
			1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total measured and indicated [1]	1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total inferred [1]	
T. 142 N., R. 81 W.													
Local bed 40 to 60 feet above base of Fort Union formation	3.6	536	----------	3.37	----------	----------	3.37	----------	----------	----------	----------	----------	3.37
T. 141 N., R. 82 W.													
Local bed 50 feet below Kuether(?)	2.4	104	0.44	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
T. 142 N., R. 82 W.													
Kuether(?)	2.3	1,898	2.63	----------	----------	----------	----------	4.94	----------	----------	----------	----------	----------
Local bed 25 feet below Kuether(?)	2.6	133	----------	0.61	----------	----------	0.61	----------	----------	----------	----------	----------	----------
Local bed 50 feet below Kuether(?)	2.4	485	2.04	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Do	3.0	203	----------	1.07	----------	----------	1.07	----------	----------	----------	----------	----------	----------
Local bed 40 to 60 feet above base of Fort Union formation	3.8	669	----------	4.46	----------	----------	4.46	----------	----------	----------	----------	----------	----------
Total	-------	-------	5.67	6.14	----------	----------	6.14	4.94	----------	----------	----------	----------	6.14
T. 143 N., R. 82 W.													
Local bed 170 feet above base of Fort Union formation	3.3	1,085	----------	3.59	----------	----------	3.59	----------	4.98	----------	----------	4.98	----------
Local bed 140 feet above base of Fort Union formation	2.9	109	----------	.55	----------	----------	.55	----------	----------	----------	----------	----------	----------
Local bed 115 feet above base of Fort Union formation	2.8	66	----------	.32	----------	----------	.32	----------	----------	----------	----------	----------	----------
Total	-------	-------	----------	4.46	----------	----------	4.46	----------	4.98	----------	----------	4.98	9.44

T. 141 N., R. 83 W.

Local bed 25 feet above Kuether	4.2	662		4.87			4.87						
Kuether	3.9	4,704		16.20			16.20		14.28			14.28	
Do	5.3	295			2.72		2.72						
Hagel	7.4	2,662								34.48		34.48	
Yeager	1.8	4,051	5.94					6.65					
Local bed 120 feet below Hagel	2.1	773	2.84										
Total			8.78	21.07	2.72		23.79	6.65	14.28	34.48		48.76	72.55

T. 142 N., R. 83 W.

Local bed 150 feet above Hagel	2.0	174	0.61										
Local bed 90 to 110 feet above Hagel	2.5	136		0.60			0.60						
Kuether	3.8	608		4.00			4.00						
Do	5.6	147			0.72		.72			0.72		0.72	
Hagel	3.8	203		1.35			1.35						
Do	6.0	5,973			19.40		19.40			43.78		43.78	
Do	10.5	422				7.76	7.76						
Yeager	1.6	211	.55					0.05					
Do	8.9	768			.77		.77			11.19		11.19	
Total			1.16	5.95	20.89	7.76	34.60	.05		55.69		55.69	90.29

T. 143 N., R. 83 W.

Local bed 90 to 110 feet above Hagel	2.0	338	1.20										
Hagel	6.1	7,303			12.91		12.91			63.45		63.45	
Yeager	2.2	6,702	5.23					20.57					
Stanton	2.4	296	1.24										
Do	2.8	6,336		7.11			7.11		23.41			23.41	
Brazda	2.3	870	3.53										
Do	2.8	5,805		4.05			4.05		24.03			24.03	
Local bed 80 feet below Brazda	2.4	634	.80					1.81					
Do	2.8	982		4.31			4.31		.48			.48	
Local bed 110 feet below Brazda	2.1	110	.41										
Do	4.0	494		3.46			3.46						
Total			12.41	18.93	12.91		31.84	22.38	47.92	63.45		111.37	143.21

TABLE 5.—*Estimated reserves of coal in the Square Buttes coal field, North Dakota*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of the thickness shown—										
			Measured and indicated					Inferred					Total measured and indicated and inferred [1]
			1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total measured and indicated [1]	1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total inferred [1]	
T. 144 N., R. 83 W.													
Local bed 80 feet below Brazda	3.5	182		0.81			0.81		0.32			0.32	
Local bed 110 feet below Brazda	2.1	16	0.06										
Total			0.06	0.81			0.81		0.32			0.32	1.13
T. 141 N., R. 84 W.													
Kuether	1.9	539	1.79										
Do	4.0	2,077		10.44			10.44		3.95			3.95	
Do	7.1	7,437			23.86		23.86			68.82		68.82	
Hagel	3.6	706		4.45			4.45						
Do	7.4	5,155			12.27		12.27			54.29		54.29	
Do	10.3	6,707				36.10	36.10				84.36	84.36	
Total			1.79	14.89	36.13	36.10	87.12		3.95	123.11	84.36	211.42	298.54
T. 142 N., R. 84 W.													
Local bed 35 feet above Red Butte	1.5	40	0.11										
Do	3.1	54		0.15			0.15		0.15			0.15	
Kuether	2.0	422	.26					1.22					
Do	3.5	4,482		8.04			8.04		19.41			19.41	
Do	5.4	4,165			9.45		9.45			30.11		30.11	
Hagel	6.3	489			5.83		5.83			.17		.17	
Do	12.3	26,890				120.78	120.78				456.25	456.25	
Yeager	2.2	42						.16					
Do	4.4	187							1.44			1.44	
Do	8.7	2,725			15.40		15.40			26.09		26.09	
Total			.37	8.19	30.68	120.78	159.65	1.38	21.00	56.37	456.25	533.62	693.27

T. 143 N., R. 84 W.

Local bed 35 feet above Red Butte	3.0	421		0.97			0.97		1.24			1.24	
Red Butte	5.0	267			1.50		1.50			0.84		.84	
Kuether	2.0	395						1.38					
Hagel	6.4	2,382			1.46		1.46			25.26		25.26	
Yeager	2.2	2,800	1.67					91.53					
Do	3.5	12,176		15.85			15.85		58.33			58.33	
Do	6.0	2,046			19.47		19.47			2.02		2.02	
Berg	3.5	3,619		12.07			12.07		9.80			9.80	
Do	5.9	1,939			10.28		10.28			10.68		10.68	
Local bed 25 feet above Stanton	1.8	67	.21										
Stanton	1.7	5,726	3.21					14.27					
Do	3.4	7,429		12.48			12.48		31.41			31.41	
Brazda	2.2	6,085	4.41					18.84					
Do	3.1	4,762		5.95			5.95		19.52			19.52	
Total			9.50	47.32	32.71		80.03	126.02	120.30	38.80		159.10	239.13

T. 144 N., R. 84 W.

Yeager	1.8	90	0.12					0.17					
Berg	6.5	499								5.68		5.68	
Local bed 25 feet above Stanton	1.8	451	1.42										
Stanton	3.9	785		4.24			4.24		1.13			1.13	
Brazda	2.5	333		.92			.92		.53			.53	
Total			1.54	5.16			5.16	.17	1.66	5.68		7.34	12.50

T. 141 N., R. 85 W.

Local bed 35 feet above Red Butte	1.9	126	0.42										
Red Butte	5.0	4,091			3.85		3.85			31.95		31.95	
Local bed 35 feet below Red Butte	3.0	656		3.44			3.44						
Do	5.0	640			5.60		5.60						
Local bed 100 feet above Otter Creek	3.5	709							4.39			4.39	
Kuether	3.0	3,230		3.10			3.10		13.86			13.86	
Hagel	10.3	75									1.36	1.36	
Total			.42	6.54	9.45		15.99		18.25	31.95	1.36	51.56	67.55

TABLE 5.—*Estimated reserves of coal in the Square Buttes coal field, North Dakota*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of the thickness shown—										
			Measured and indicated					Inferred					Total measured and indicated and inferred [1]
			1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total measured and indicated [1]	1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total inferred [1]	
T. 142 N., R. 85 W.													
Local bed 55 feet above Red Butte	2.5	54		0.24			0.24						
Local bed 35 feet above Red Butte	2.1	898	1.48					1.74					
Red Butte	2.3	1,566	1.58					4.64					
Do	2.9	2,877		2.21			2.21		12.57			12.57	
Do	5.3	12,920			1.23		1.23			110.28		110.28	
Do	10.5	282				5.18	5.18						
Local bed 65 feet below Red Butte	2.0	99	.35										
Kuether	2.0	262						.92					
Do	3.2	3,027		1.71			1.71		14.63			14.63	
Hagel	15.3	302									8.10	8.10	
Total			3.41	4.16	1.23	5.18	10.57	7.30	27.20	110.28	8.10	145.58	156.15
T. 143 N., R. 85 W.													
Local bed 35 feet above Red Butte	3.9	1,672		2.97			2.97		8.38			8.38	
Red Butte	2.1	78	0.29										
Do	3.0	98		.51			.51						
Do	5.2	5,277			10.07		10.07			38.18		38.18	
Local bed 35 feet below Red Butte	4.8	94		.79			.79						
Do	5.4	600			2.56		2.56			3.15		3.15	
Local bed 60 feet below Red Butte	4.0	744		1.12			1.12		4.09			4.09	
Kuether	2.0	179						0.63					
Do	3.3	882		.98			.98		4.11			4.11	
Yeager	2.8	1,790							8.77			8.77	
Berg	6.5	1,901			0.58		.58			21.04		21.04	
Stanton	3.1	1,667							9.05			9.05	
Brazda	2.5	328							1.44			1.44	
Total			.29	6.37	13.21		19.58	.63	35.84	62.37		98.21	117.79

T. 144 N., R. 85 W.

Berg	6.5	174								1.98		1.98	
Stanton	3.1	461							2.50			2.50	
Total									2.50	1.98		4.48	4.48

T. 141 N., R. 86 W.

Local bed 100 feet above Otter Creek	3.2	10,923		12.13			12.13		49.31			49.31	
Local bed 55 feet above Otter Creek	4.8	1,030							8.66			8.66	
Local bed 45 to 50 feet above Otter Creek	2.0	1,403	1.48					3.43					
Do	3.6	1,614		2.43			2.43		7.74			7.74	
Upper Otter Creek	2.4	6,882	3.86					25.03					
Do	2.5	32		.14			.14						
Lower Otter Creek	3.7	1,491							9.66			9.66	
Total			5.34	14.70			14.70	28.46	75.37			75.37	90.07

T. 142 N., R. 86 W.

Red Butte	2.2	320	1.23										
Do	3.5	4,986		2.19			2.19		28.41			28.41	
Byer	2.4	414	1.74										
Do	3.3	3,579		6.25			6.25		14.17			14.17	
Local bed 55 feet above Otter Creek	4.8	120							1.01			1.01	
Local bed 45 to 50 feet above Otter Creek	2.0	378	.31					1.01					
Upper Otter Creek	2.4	1,179	4.95										
Do	3.2	9,779		7.26			7.26		46.65			46.65	
Lower Otter Creek	1.9	3,015	3.13					6.90					
Do	3.1	10,698		4.20			4.20		53.59			53.59	
Buckmann	2.4	2,304	3.78					5.90					
Total			15.14	19.90			19.90	13.81	143.83			143.83	163.73

TABLE 5.—*Estimated reserves of coal in the Square Buttes coal field, North Dakota*—Continued

Coal bed	Average thickness (feet)	Area (acres)	Reserves, in millions of short tons, in beds of the thickness shown—										
			Measured and indicated					Inferred					Total measured and indicated and inferred [1]
			1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total measured and indicated [1]	1.5–2.5 feet	2.5–5 feet	5–10 feet	More than 10 feet	Total inferred [1]	
T. 143 N., R. 86 W.													
Red Butte	3.9	2,920		2.78			2.78		17.51			17.51	
Do	5.0	708			5.65		5.65			0.55		.55	
Local bed 35 feet below Red Butte	5.5	85			.21		.21			.71		.71	
Local bed 60 feet below Red Butte	4.0	682		.65			.65		4.12			4.12	
Byer	3.3	2,223		4.60			4.60		8.36			8.36	
Upper Otter Creek	2.2	643	2.46										
Lower Otter Creek	1.8	174	.55										
Do	2.7	5,864		2.59			2.59		24.64			24.64	
Otter Creek	7.0	2,600			6.10		6.10			25.75		25.75	
Buckmann	2.4	51						0.22					
Upper Beulah-Zap	2.3	1,978						7.96					
Do	3.5	8,314		4.81			4.81		45.88			45.88	
Lower Beulah-Zap	4.0	1,195		2.17			2.17		6.19			6.19	
Total			3.01	17.60	11.96		29.56	8.18	106.70	27.01		133.71	163.27
T. 144 N., R. 86 W.													
Otter Creek	7.0	509			1.37		1.37			4.86		4.86	
Upper Beulah-Zap	3.6	1,805		5.08			5.08		6.18			6.18	
Lower Beulah-Zap	4.0	539		.52			.52		3.25			3.25	
Total				5.60	1.37		6.97		9.43	4.86		14.29	21.26
T. 141 N., R. 87 W.													
Local bed 205 to 210 feet above Otter Creek	1.8	192	0.61										
Local bed 55 feet above Otter Creek	4.8	4,552		6.79			6.79		31.45			31.45	
Upper Otter Creek	2.5	230							1.01			1.01	
Total			.61	6.79			6.79		32.46			32.46	39.25

T. 142 N., R. 87 W.

Local bed 55 to 70 feet above Otter Creek	2.3	409	1.65										
Do	3.2	4,968		2.72			2.72		24.96			24.96	
Local bed 35 feet above Otter Creek	2.5	844		3.71			3.71						
Upper Otter Creek	2.3	106	.43										
Do	2.8	10,633		16.73			16.73		34.27			34.27	
Lower Otter Creek	3.5	11,709		12.66			12.66		48.75			48.75	
Herman	1.7	110	.33										
Do	2.9	8,135		5.67			5.67		35.80			35.80	
Buckmann	2.4	837	.52					3.00					
Do	2.5	2,114							9.25			9.25	
Upper Beulah-Zap	2.3	403						1.62					
Total			2.93	41.49			41.49	4.62	153.03			153.03	194.52

T. 143 N., R. 87 W.

Upper Otter Creek	2.2	110	0.42										
Do	2.5	862							3.77			3.77	
Lower Otter Creek	1.8	27						0.09					
Do	3.4	1,443		0.64			0.64		8.04			8.04	
Herman	4.3	3,543		12.09			12.09		21.64			21.64	
Buckmann	1.8	229	.72										
Do	3.1	5,596		8.45			8.45		22.33			22.33	
Schoolhouse	2.3	336	1.34										
Do	3.0	434		2.24			2.24						
Upper Beulah-Zap	2.2	5,036	6.26					12.90					
Do	2.6	8,021		8.40			8.40		27.67			27.67	
Lower Beulah-Zap	2.3	27	.11										
Do	4.0	2,543		2.05			2.05		15.38			15.38	
Spaer	2.0	306	1.07										
Do	4.6	10,280							82.75			82.75	
Do	6.1	1,084			11.62		11.62						
Local bed 45 to 50 feet below Spaer	3.5	3,549		2.83			2.83		19.42			19.42	
Total			9.92	36.70	11.62		48.32	12.99	201.00			201.00	249.32

T. 144 N., R. 87 W.

Upper Beulah-Zap	2.2	17	0.06										
Spaer	2.8	493							2.42			2.42	
Do	3.4	718							4.27			4.27	
Local bed 45 to 50 feet below Spaer	3.5	1,785		4.14			4.14		6.80			6.80	
Local bed 85 to 90 feet below Spaer	4.4	343		2.64			2.64						
Total			.06	6.78			6.78		13.49			13.49	20.27
Grand total			82.85	302.92	169.48	185.22	657.62	237.58	1,033.51	616.03	550.07	2,199.61	2,857.23

[1] Reserves in beds 1.5 to 2.5 feet thick not included in summary totals.

dicated reserves but within 2 miles of the outcrop. The reserves in the three categories were calculated separately, but because of the limited number of measured coal thicknesses, the writers combined the measured and indicated reserves.

TABLE 6.—*Estimated reserves of coal in the Square Buttes coal field, North Dakota, by beds*

Coal bed	Reserves, in millions of short tons, in beds of the thickness shown—								
	Measured and indicated				Inferred				Total measured and indicated and inferred
	2.5–5 feet	5–10 feet	More than 10 feet	Total measured and indicated	2.5–5 feet	5–10 feet	More than 10 feet	Total inferred	
Red Butte	7.69	22.30	5.18	35.17	58.49	181.80		240.29	275.46
Kuether	44.47	36.75		81.22	70.24	99.65		169.89	251.11
Hagel	5.80	51.87	164.64	222.31		221.43	550.07	771.50	993.81
Yeager	15.85	35.64		51.49	68.54	39.30		107.84	159.33
Berg	12.07	10.86		22.93	9.80	39.38		49.18	72.11
Stanton	23.83			23.83	67.50			67.50	91.33
Brazda	10.92			10.92	45.52			45.52	56.44
Byer	10.85			10.85	22.53			22.53	33.38
Otter Creek	44.22	7.47		51.69	230.38	30.61		260.99	312.68
Herman	17.76			17.76	57.44			57.44	75.20
Buckmann	8.45			8.45	31.58			31.58	40.03
Schoolhouse	2.24			2.24					2.24
Beulah-Zap	23.03			23.03	104.55			104.55	127.58
Spaer		11.62		11.62	89.44			89.44	101.06
Local beds	75.74	8.37		84.11	177.50	3.86		181.36	265.47
Grand total	302.92	184.88	169.82	657.62	1,033.51	616.03	550.07	2,199.61	2,857.23

TOWNSHIP DESCRIPTIONS

The Square Buttes coal field includes 15 full townships and fractional parts of 13 others arranged in 4 tiers of 7 townships each. The tiers are designated from south to north, T. 141 N. through T. 144 N.; the townships in each tier are from east to west, R. 81 W. through R. 87 W. "Fractional" indicates that only a part of the township is within the Square Buttes field.

T. 141 N., R. 81 W. (FRACTIONAL)

The Square Buttes portion of T. 141 N., R. 81 W., is bounded on the east by the southward-flowing Missouri River, which has, in most places, a flood plain from a few hundred feet to 1½ miles wide. The country rises from the gravel-covered terraces adjacent to the flood plain to a deeply dissected upland in the western part of the township, 200 to 420 feet above the river. A conspicuous feature of this township is the group of high, sandstone-capped buttes, known as Square Buttes, in secs. 3, 9, and 10.

About 250 feet of marine shale and sandstone of the Cannonball formation crops out in an irregular belt half a mile to 1½ miles wide between the Missouri River flood plain and the upland in the west, which is underlain by sandstones of the Fort Union. The contact

between these two formations can be traced easily in the deep valleys that cut the upland.

No mappable coal beds were found in this township, but an 18-inch bed about 100 feet above the base of the Fort Union was formerly mined in secs. 17 and 19.

T. 141 N., R. 82 W.

Square Butte Creek flows in a broad valley from the northwest corner to the southeast corner of T. 141 N., R. 82 W. The remnant of an upland surface is present along the Square Butte Creek–Missouri River drainage divide, which extends southeastward across the northeast quarter of the township. The rest of the township is deeply dissected by erosion; the southwest quarter has been eroded to "badlands." The maximum relief is about 460 feet.

The upper part of the Cannonball formation is exposed in the valley of Square Butte Creek in the southeastern part of the township. The rest of the township is underlain by the Fort Union formation. Till of Wisconsin age occurs on the more gentle slopes, particularly in the northeast and north-central parts.

Only one bed of mappable thickness (2 feet) was found in T. 141 N., R. 82 W., but beds less than 2 feet thick have been mined at several places. The 1-foot 6-inch coal formerly mined in sec. 9 is in a bed about 85 feet above the base of the Fort Union formation. A bed, ranging in thickness from 6 inches to about 2 feet, formerly was stripped in small pits in secs. 20 and 30; this bed is about 120 feet above the base of the Fort Union. The coal formerly mined in sec. 18 is reported to be about 2 feet thick. The abandoned pit in sec. 3 is on a bed 50 feet below a bed questionably correlated with the Kuether bed; the coal is not exposed in this township, but in T. 142 N., R. 82 W., it is 2 feet 5 inches thick.

T. 141 N., R. 83 W.

(Plate 4)

The deep valley of Square Butte Creek, with a flood plain 400 to 1,700 feet wide, crosses the north-central and northeast parts of the township. A large, deeply incised tributary that drains the southern two-thirds of the township discharges into the creek in sec. 11. Another large tributary flows across the northwest corner of the township and empties into the creek in sec. 32, T. 142 N., R. 83 W. The broad stream divides are deeply dissected by many stream valleys. The maximum relief is about 350 feet.

The Fort Union formation underlies all of the township and is well exposed in the deep stream valleys and on some of the higher, more rugged divides which are covered by till of Wisconsin age.

The numerous coal beds that crop out in this township have been mined at many places, but only five beds contain coal of mappable thickness. A local bed 120 feet below the Hagel bed, cropping out along Square Butte Creek, contains 2 feet of coal at locality 173 and 2 feet 2 inches at locality 174. The bed thins to the south and east, is only 1 foot 5 inches thick at a mine on the west side of sec. 14, and is probably less than 2 feet thick at an abandoned mine at the north edge of the same section.

The Yeager bed, 50 feet below the Hagel, crops out in the northwest and south-central parts of the township. Although measured sections show that the coal is only 1 foot 2 inches to 1 foot 9 inches thick, the bed has been mined at many places along the outcrop.

The Hagel bed, which is present in a small area in secs. 5, 6, 7, and 8, formerly was mined at several strip pits in sec. 7. An incomplete section of the bed along the road between secs. 5 and 6 shows 1 foot 10 inches of coal, but a mile to the east the coal is replaced entirely by carbonaceous shale. A coal at the horizon of the Hagel bed has been mined in sec. 35, but is not now exposed.

The Kuether bed, 35 feet above the Hagel, is the thickest and most extensive bed in the township. It crops out in the west half of the area and has been extensively mined in secs. 21, 28, and 29. At locality 175, on the road between secs. 5 and 6, the coal is 5 feet 9 inches thick and is 5 feet thick at locality 176 in sec. 9. The bed thins rapidly to the east; it contains only 2 feet 6 inches of coal at locality 177 in sec. 4. To the south, in sec. 21, the Kuether bed is 3 feet thick at locality 178. A power auger drilled through 3 feet 3 inches of coal in the bed at locality 179d. The Kuether bed could not be traced accurately across the rolling country in the southeast quarter of the township.

A local bed 25 feet above the Kuether crops out in a small area in secs. 28, 29, 32, and 33. An incomplete section measured at the mine in sec. 33 shows 4 feet 2 inches of coal; the bottom of the bed is covered by water. This bed has been mined also in the northeast corner of sec. 32, but the coal is not exposed. Several thin beds in the stratigraphic section above this bed have yielded small amounts of coal at strip pits in secs. 8, 17, 30, and 31.

T. 141 N., R. 84 W.

(Plate 4)

All of T. 141 N., R. 84 W., except about 6 square miles in the southwest quarter and 2 square miles in the southeast corner, is drained by a large tributary of Square Butte Creek that flows eastward across the northern one-third of the township. The land, a gently undulating plain, rises gradually to the Square Butte Creek–

Sweetbrier Creek drainage divide that trends northwestward across the township from sec. 34 to sec. 29. The streams in the area become progressively more entrenched as they flow to the north and east towards Square Butte Creek. The maximum relief in the township is about 340 feet.

About 230 feet of the Fort Union formation underlies the surface of the township. The best exposures are in the deep stream valleys along the north and east edges of the area. Scattered patches of till occur on some of the gentle slopes.

The Hagel and Kuether beds, the only ones of economic importance in the township, crop out in the valleys of the large tributaries of Square Butte Creek along the north and east edges of the area. The Yeager bed is present in the valley of the large stream in sec. 1, but its outcrop is concealed by alluvium.

The Hagel bed, which was named from the Hagel mine in sec. 2, is the most important bed in the Square Buttes coal field. At the north pit of the Hagel mine, locality 135, the coal is 10 feet 6 inches thick but is split by a 3-inch clay parting 2 feet above the base. The Hagel bed is also exposed in a strip pit about 2,000 feet southwest of the north pit. In an abandoned pit in the SW¼ sec. 2, locality 136, 9 feet 8 inches of coal is exposed; the base of the bed is covered. At locality 137, 6 feet 4 inches of the Hagel coal, broken by a clay parting 1 foot 6 inches thick, is visible. At locality 138d a power auger drilled through 10 feet 3 inches of coal in this bed, which is split by 3 partings 6 inches to 1 foot 3 inches thick. At locality 139, 4 feet 2 inches of the Hagel bed is exposed. Along the east side of the township the bed contains 7 feet 5 inches of coal in an abandoned mine at locality 140.

The Kuether bed, which is 45 feet above the Hagel bed, has been mined extensively in the east-central part of the township, but no complete exposure was found. At locality 144 the Kuether bed consists of 8 feet 8 inches of coal, broken by a 2-inch clay parting near the base. About half a mile to the south, in the Kuether mine, locality 146, the parting is 1 foot 2 inches thick. In the Glenn-Burn mine, locality 145, 6 feet 11 inches of coal overlies the clay parting; 2 to 3 feet of coal is reported to underlie the parting. At localities 147 and 148, in secs. 13 and 24, respectively, the Kuether bed contains a parting 3 feet 6 inches to 4 feet 2 inches thick in the upper part of the bed. Auger holes drilled in the Kuether bed near the northwest corner of the township, localities 141d, 142d, and 143d, revealed that the bed is split by partings into several coal seams, the thickest of which is 4 feet 6 inches.

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T. 141 N., R. 85 W.

(Plate 4)

Most of T. 141 N., R. 85 W., is drained southward by a tributary of Sweetbrier Creek, but a small area in the northeast corner drains eastward to Square Butte Creek, and a narrow belt along the west side is within the Otter Creek drainage basin. The area is rolling country of moderate relief with low ridges and buttes capped by siliceous rocks along some of the stream divides. Remnants of an extensive system of glacial diversion channels are present along the east side of the township in secs. 1, 11, 12, 13, 14, 23, and 24. An esker in secs. 13 and 14, known locally as Chain Hill, forms a conspicuous ridge about 1½ miles long that stands about 50 feet above the surrounding country. The maximum relief in the area is about 300 feet.

The Fort Union formation is present throughout this township, but because of the cover of grass and farm crops, the rocks are not well exposed. Scattered patches of Wisconsin till remain as erosional remnants on a few gentle slopes, and glacial material floors several of the larger diversion channels.

A local bed 35 feet below the Red Butte bed is the lowest of the three beds that crop out in this township. An auger hole, drilled at locality 94d near two abandoned mines in sec. 18, disclosed 5 feet of coal in this bed. To the east, in sec. 15, locality 93d, drilling disclosed 3 feet of coal which was overlain by 14 feet of shale and then by 6 inches of coal.

The Red Butte bed was traced through most of the area north of the large tributary of Sweetbrier Creek and in a small area south of that stream. A power auger drilled through 5 feet of coal in this bed at locality 95d near an abandoned mine in sec. 8. The bed also has been stripped in a pit in sec. 22, but the coal is not exposed. A local bed 35 feet above the Red Butte bed crops out in a small area of secs. 21 and 22. At locality 96, in a cut on the road between secs. 21 and 22, the bed contains 1 foot 11 inches of weathered coal broken by a 2-inch clay parting.

T. 141 N., R. 86 W.

(Plate 4)

T. 141 N., R. 86 W., is drained by three stream systems: Otter Creek and its tributaries in the northern two-thirds; southward-flowing tributaries of Hailstone Creek in the southwest; and southeastward-flowing Sweetbrier Creek in the southeast. The northern part of the township is rolling country of moderate relief, but southward from the flood plain of Otter Creek the land rises about 300 feet to an upland surface that has a rather steep north face. Erosional remnants of former drainage channels are evidence that glacial

melt water once spilled across this upland surface. The rough, hilly Otter Creek–Sweetbriar Creek divide in the southeast quarter of the township is covered by glacial boulders and broken by several deep glacial diversion channels that contain glacial deposits and large undrained depressions. The hills in sec. 36 are paved with large, irregular blocks of siliceous rocks.

The most prominent physiographic feature of this township is in sec. 27 where a steep-sided butte rises about 100 feet above the surrounding country. This butte exhibits one of the best outcrops of the Golden Valley formation, which also crops out in secs. 16, 17, 20, and 21, but which has not been recognized in any other township of the coal field. About 265 feet of the Fort Union formation underlies the Golden Valley in this township.

Abandoned strip pits mark the horizon of the upper member of the Otter Creek bed along Otter Creek in secs. 3 and 4 and in a small area along a stream in secs. 4 and 5. At locality 68, the only outcrop of this member, the coal is 2 feet 3 inches thick.

A local bed 45 to 50 feet above the base of the Otter Creek bed was mapped in the northern part of the township in secs. 3, 4, 5, 10, and 11. This bed is at the approximate horizon of the Byer bed, but because the areas of outcrop are widely separated, no attempt was made to correlate them. At locality 67, the coal is 2 feet thick but is broken by two thin partings. A large amount of coal was dug from this bed at locality 69 where it consists of two coal seams separated by 4 feet 11 inches of interbedded shale and coal; the upper coal is 3 feet 7 inches thick and the lower is more than 1 foot thick.

Three abandoned mines along Otter Creek in secs. 10 and 11 indicate a coal bed 70 to 75 feet above the Otter Creek bed, but exposures of this coal were not found in the township. A bed 100 feet above the Otter Creek crops out along the upper course of Otter Creek and along Sweetbriar Creek across the divide to the south. In the northwest corner of sec. 14, locality 70, the lower 3 feet 3 inches of the bed is exposed below a layer of gravel. About a mile to the south at locality 71, in sec. 15, the coal is 3 feet 10 inches thick, and in the valley of Sweetbriar Creek the coal at localities 72, 73, and 74 is from 2 feet 3 inches to 3 feet 8 inches thick. A coal of unknown thickness about 40 feet below this bed was prospected in a small pit just south of the township line. Coal was mined formerly in an open pit in sec. 21 from a bed about 160 feet above the Otter Creek bed, but the coal is no longer exposed.

T. 141 N., R. 87 W. (FRACTIONAL)

(Plate 4)

All of T. 141 N., R. 87 W., within the Square Buttes coal field except that part west of longitude 101° 45′ which is included in the

Knife River area. The land is drained by streams of three drainage systems: the west half by northwestward-flowing tributaries of Beaver Creek; the northeast by northward-flowing tributaries of Otter Creek; and the southeast by southward-flowing Hailstone Creek. Scattered hills and ridges covered by blocks of siliceous rock rise above the rolling country in the northern and western parts of the township. These hills are so numerous in sec. 16 that they give the land a pimpled appearance. Deep valleys, one-eighth to one-fourth of a mile wide, eroded by glacial melt water, break the stream divides. The rolling country breaks away along the divide at the head of Hailstone Creek to a gentle erosional plain that characterizes the southern and eastern parts of the township.

About 300 feet of strata in the upper part of the Fort Union formation is exposed in T. 141 N., R. 87 W. The till deposited over the area during the Wisconsin stage of glaciation is now represented only by scattered glacial boulders and spotty erosional remnants along the large stream in the northeast corner of the township. Most of the old diversion channels and the upper valley of Hailstone Creek are floored with diversion channel fill.

This township is almost devoid of coal outcrops. A local bed 55 to 70 feet above the Otter Creek bed underlies the northeast corner, where drilling with a power auger at locality 44d showed 4 feet 9 inches of coal broken by two thin clay partings. A thin coal, approximately 210 feet above the base of the Otter Creek bed, crops out at three places in the southwest quarter of the township, but at only one place is the bed thought to be more than 2 feet thick. In sec. 31, locality 45d, 1 foot 10 inches of coal was measured in a drill hole. Because the coal was oxidized, it is assumed that the measured thickness is less than the true thickness.

T. 142 N., R. 81 W. (FRACTIONAL)

The Missouri River flows along the east side of this fractional part of T. 142 N., R. 81 W. Sherk Creek and a large unnamed creek flow across the southwest quarter of the township through deep flat-bottomed valleys and discharge into the river in sec. 28. The west side of the Missouri valley rises abruptly from the river terraces to a till-covered upland. High, sandstone-capped buttes, the most prominent of which is 360 feet above the river, are found in secs. 19, 30, 33, and 34.

Rocks of the upper part of the Cannonball formation crop out in an irregular belt between the river terraces and the base of the upland to the west. The contact with the overlying Fort Union formation is well exposed in the southern part of the township, but is obscured in the north by till and terrace deposits.

This township is devoid of coal, except for several thin beds in a zone 40 to 60 feet above the base of the Fort Union. Clinker at two places along the west side of the township marks the horizon of this zone. According to Smith (1909, p. 22), 3 feet 6 inches of dirty lignite is present in an abandoned mine on the line between secs. 6 and 7.

T. 142 N., R. 82 W.

(Plate 5)

The surface of T. 142 N., R. 82 W., is a rolling upland of moderate relief cut by deep steep-sided stream valleys. The northwest part drains northward to a large unnamed creek in T. 143 N., R. 82 W.; secs. 1 and 2 drain through a short tributary directly into the Missouri River; the center of the township is drained to the east through the broad, flat valley of Sherk Creek; the southwest part is within the Square Butte Creek drainage basin; and a large northeastward-flowing creek carries the runoff from the southeast corner to the Missouri. The maximum relief in the area is about 430 feet.

Most of the township is underlain by approximately 375 feet of Fort Union strata, but the upper 30 feet of the Cannonball formation crops out in the valley of Sherk Creek in secs. 13 and 24. All the township, except the stream valleys and other deeply eroded areas, is mantled by till. The valley of Sherk Creek and the valley of the stream that drains the northwest corner of the area served as glacial melt water channels during the Pleistocene; the upper part of those stream valleys is floored with the diversion channel deposits.

Coal in a zone 40 to 60 feet above the base of the Fort Union formation is present in the deep valleys along the east side of the township, but no measured thicknesses were obtained. About 4 feet of shaly coal was reported in two open pits in sec. 24 and 3 and 4 feet in an old mine in sec. 25.

A local bed 50 feet below the Kuether(?) bed crops out along Sherk Creek in the northwest quarter and along the south edge of the township in secs. 29, 31, 32, 33, and 34. The coal is 3 feet thick at locality 184 in sec. 16, and 2 feet 5 inches thick at locality 185 in sec. 32. A mile west of locality 185 the coal is less than 2 feet thick. A local bed 25 feet below the Kuether(?) bed was found in secs. 2 and 3; it is 2 feet 7 inches thick at locality 186.

A bed tentatively correlated with the Kuether has been mined at several places in the township. A partial exposure of the bed at locality 187 in sec. 32 shows 2 feet 3 inches of coal with a 2-inch parting; the total thickness is reported to be about 4 feet. The bed also was reported to be 4 feet thick in an old mine in the SW¼ sec. 27. Two abandoned mines in secs. 7 and 18 mark the horizon of the Kuether(?) bed in the northwest quarter of the township.

T. 142 N., R. 83 W.

(Plate 5)

All of T. 142 N., R. 83 W., except for a small area along the north and east edges, is within the drainage basin of the southeastward-flowing Square Butte Creek. The areas along the north and east edges drain to the Missouri River through Sherk and Mandan Lake Creeks and through the tributaries of a large unnamed creek in T. 143 N., R. 82 W. Most of the township is a rolling upland, dotted by numerous undrained depressions, that has been deeply incised on the south and west by Square Butte Creek and its tributaries. The valley of Square Butte Creek is 150 to 180 feet below the general level of the land, but the maximum relief in the township is about 350 feet. A large glacial diversion channel extends southward across the upland from sec. 2 to sec. 27.

About 325 feet of the Fort Union formation crops out in this township, but the rocks are exposed well only along Square Butte Creek, in the stream valleys along the west side of the township, and in a small dissected area in the southeast corner. Till of Wisconsin age covers most of the upland, and diversion channel deposits fill the larger diversion channels.

The Yeager bed, the lowest stratigraphically in the township, crops out in the valley of Square Butte Creek. The coal is not exposed, but the bed was reported by Leonard (1925, p. 139) to be 7 to 9 feet thick, including a 10-inch clay parting, in the abandoned mines on the west side of sec. 29. The Yeager bed could not be traced eastward from its outcrop in that section.

The Hagel bed, which crops out mainly in the southwest quarter, is the thickest bed in the area. Even though it has been mined at several places, the only exposure is at locality 170 in the NE¼ sec. 19, where the upper 4 feet 1 inch of the bed crops out; the total thickness was reported to be about 6 feet. The Hagel bed also was reported to contain about 6 feet of coal in the abandoned mines in sec. 21. Clinker is abundant on the Hagel along its outcrop in sec. 31.

The Kuether bed, 45 feet above the Hagel, crops out along the large tributary of Square Butte Creek on the west side of the township and in small areas in the southeast and southwest corners. The bed has been mined in small pits in secs. 6, 7, and 8, but the thickness of the coal could not be determined. A weathered section of the bed is exposed on the road along the west side of sec. 30. A bed tentatively correlated with the Keuther crops out in the rough country in the southeast corner of the township; the upper 4 feet 1 inch is exposed at locality 171 in sec. 26.

A thin bed in a coal zone 90 to 110 feet above the Hagel bed is present in secs. 5 and 6; it was reported to be 2½ feet thick in the

old mine in sec. 5. A local bed 150 feet above the Hagel bed, the highest coal stratigraphically in the area, crops out on a stream divide in secs. 8, 17, and 20. At locality 172, the bed contains 7 inches of coal, overlain by 1 foot of carbonaceous shale, and then 2 feet of coal.

T. 142 N., R. 84 W.

(Plate 5)

Square Butte Creek flows southeastward across the middle of the township in a flat valley 300 to 2,000 feet wide. North of the creek the surface slopes up gradually to a plain about 245 feet above the valley bottom. In some places along the southern margin of this plain, the surface is dissected into sharp, narrow, sandstone-capped ridges. South of the creek the rise to the upland is more abrupt; the maximum elevation above the valley bottom is about 300 feet. Three broad, deep channels were cut in this township by glacial melt water during the Pleistocene; one extends southward from T. 143 N., R. 84 W., and connects with the valley of Square Butte Creek in sec. 5; another cuts across secs. 1 and 12; and the third channel extends southeastward into sec. 18 from T. 142 N., R. 85 W.

Except for the narrow band of Recent alluvium along the streams and scattered deposits of till and diversion channel fill, the rocks that underlie the surface of this township belong to the Fort Union formation; more than 210 feet of this formation is exposed.

The Yeager bed, 30 feet below the Hagel, crops out along Square Butte Creek on the east side of the township. At the Schenk mine, locality 128 in sec. 25, 8 feet 11 inches of good coal is exposed. This bed formerly was mined to the north in secs. 13 and 24 where the coal is now concealed.

The Hagel bed, the most important economically in the township, crops out along both sides of Square Butte Creek. At the Schmidt mine, locality 129 in sec. 13, the upper 8 feet 3 inches of the reported 10-foot thickness is exposed. The Hagel thickens westward; in a mine adjacent to the cemetery west of Center the bed is 18 feet 11 inches thick, but the upper 8 feet 4 inches is split by five thin partings. The bed was reported to contain about 15 feet of coal with a 2½-foot clay parting in the upper 5 feet in the abandoned underground workings of the old Superior Coal Co. about one-half mile north of the cemetery. Two beds of coal, separated by 3 feet 1 inch of shale, constitute the Hagel bed in the abandoned mine in sec. 8, locality 130. The upper bed contains 5 feet 4 inches of good coal; two thin partings are near the top of the 6 feet 5 inches of coal exposed in the lower bed. Clinker masses mark the horizon of the Hagel bed southeast of Center, but the coal is not exposed.

The Kuether bed, 45 feet above the Hagel, is present along the south side of Square Butte Creek throughout the township, but on the north side of the creek it is present only in the northwest corner. The horizon of this bed could not be mapped north of the creek across the rolling country around Center. A power auger drilled through 5 feet 6 inches of coal containing a 6-inch shaly coal parting at locality 133d on the road between secs. 26 and 27. To the west, in the Light mine in the SW¼ sec. 22, only the upper 2 feet 11 inches of the Kuether bed is exposed, but the bed was reported to be 6 to 8 feet thick. The Kuether bed is assumed to thin to the northwest, because the bed was reported to contain only 2 feet of coal in an abandoned mine in sec. 6. Part of the Kuether is exposed in a large spring in the NE¼ sec. 36 where the reported thickness was 6 feet. At the abandoned mine in the SW¼ sec. 35 the bed is thought to be 4 feet thick.

A local bed 35 feet above the Red Butte bed underlies small areas along the stream divides in secs. 1, 2, 7, 18, 29, 30, and 31; at locality 134 in sec. 31 the coal is 3 feet 3 inches thick.

T. 142 N., R. 85 W.

(Plate 5)

Square Butte Creek heads in the south-central part of T. 142 N., R. 85 W., and flows to the northeast corner. The broad valley of an old glacial diversion channel merges into the creek valley in sec. 2. The township is rolling country with a maximum relief of about 230 feet. The divide between Otter and Square Butte Creeks trends in a northerly direction across the west side of the area. The Square Butte Creek–Sweetbriar Creek divide cuts across a small area along the south edge of the township. Four deep diversion channels breach the stream divides in the northeast and southwest quarters.

Rocks of the Fort Union formation, which underlie all of this township, are well exposed throughout the area. Erosional remnants of Wisconsin till are spotty, but glacial boulders are abundant, especially on the Otter Creek–Square Butte Creek divide. A segment of a large channel in the southwest corner is filled with glacial diversion channel deposits.

The Kuether bed is present but not exposed along Square Butte Creek in the northeast corner of the township; however, a hole drilled near an abandoned mine in the NW¼ sec. 2 showed 3 feet 4 inches of coal in this bed.

A bed 65 feet below the Red Butte bed contains 2 feet of coal at locality 83 on the highway between secs. 2 and 3, but this coal thins rapidly; half a mile to the southeast at locality 84, it is only 1 foot 8 inches thick.

The Red Butte bed is the thickest coal cropping out in this township: Near the north boundary at locality 85, sec. 3, the bed is 5 feet 10 inches thick, but minable only in the lower 2 feet 1 inch; it thickens rapidly southward, and at locality 86d, at the corner of secs. 9, 10, 15, and 16, a power auger drilled through 10 feet 6 inches of coal broken only by a 6-inch shale parting; in a mine about a quarter of a mile to the east, locality 87, the Red Butte bed is split by a 12-foot parting into an upper 2-foot 4-inch seam and a lower seam that is more than 3 feet 9 inches thick. At locality 88 in sec. 22, the Red Butte bed is 2 feet 8 inches thick, but perhaps only the upper part of the bed is exposed; the bed is reported to contain 4 feet of coal on the west side of sec. 22. Only 1 foot 5 inches of weathered coal was found at locality 89 on Highway 31 between secs. 22 and 23. The Red Butte bed could not be traced eastward into the adjoining township. Coal at the Red Butte horizon formerly was mined in a small strip pit in sec. 30; a large spring now flows from that pit.

A local bed 35 feet above the Red Butte coal crops out in the central and east-central parts of the township. A cut on Highway 31 south of Hannover, locality 91, reveals 2 feet 5 inches of weathered coal. The bed is only 1 foot 8 inches at locality 90. The landowner reported that the coal is slightly more than 3 feet thick in an abandoned mine in sec. 26. In secs. 12 and 13 clinker and streaks of weathered coal mark the horizon of this seam. A local bed 55 feet above the Red Butte bed crops out in a small area in secs. 21 and 28; at locality 92 it is 2 feet 6 inches thick. This bed was not recognized elsewhere in the township.

T. 142 N., R. 86 W.

(Plate 5)

Otter Creek flows across T. 142 N., R. 86 W., from the south-central part to the northwest corner in a flat valley about one-fourth of a mile wide. The east edge of the township is drained by several streams that flow in wide, flat, oversized valleys which were cut by glacial melt water. Northward-flowing Brady Creek and a southward-flowing tributary of Otter Creek head in the old valley in sec. 13. The surface on either side of Otter Creek is a gently rolling plain that rises gradually to high hills and ridges along the stream divides. Most of the tributaries of Otter Creek become progressively more entrenched as they approach the creek. The most prominent feature in this township is a large quartzite-capped butte about 200 feet high in the southwest corner.

About 340 feet of the Fort Union formation crops out in this township. Remnants of till of Wisconsin age occur in two broad, irregular bands 1 to 2 miles wide on either side of Otter Creek;

scattered glacial boulders remain on some of the steeper slopes from which erosion has removed the till; and diversion channel deposits floor the old channels along the east side of the township. Terrace remnants are extensive along Otter Creek, primarily on the west side.

Stratigraphically the Buckmann is the lowest coal in the township. Its position in Otter Creek valley is marked by several abandoned mines; the only exposure of the bed is at locality 54 in sec. 7, where the 2 feet 5 inches of coal is broken near the top by a 2-inch shale parting. Although the Herman bed can be traced along Otter Creek, the bed was not mapped because it contains only 11 inches of coal.

The Otter Creek bed, 70 feet above the Buckmann, is the most extensive coal in the township, and it has been mined at many places along Otter Creek. The two members of the Otter Creek bed are about 16 feet apart and of such variable thickness that rarely are both mappable at the same place. At locality 61, in sec. 6, both members are exposed; the lower contains 1 foot 9 inches of coal, underlain by 2 inches of ash and cinder; the upper, which is 16 feet 9 inches above, contains only 11 inches of coal. Because the lower member is oxidized and burned, the measurement given is not that of the true thickness. Less than a mile to the south, at locality 60, an incomplete exposure of the lower member reveals 2 feet of coal. The upper member, which thickens southward, has been mined at several points on the west side of Otter Creek. In sec. 20, at locality 55, the upper member consists of 4 feet 6 inches of clean coal; the lower member, about 20 feet below, has been prospected at the same place but the coal is not exposed. In the northern part of sec. 28, the lower member of the Otter Creek bed contains only 11 inches of coal, but it thickens rapidly to the southeast and at locality 57, in the southeast corner of the same section, is 4 feet 6 inches thick, including a 9½-inch clay parting near the top of the bed. The rapid variation in thickness of the lower member is demonstrated here by the fact that just 450 feet to the east at locality 56 the bed contains only 2 feet 9½ inches of coal and the clay parting has increased in thickness to 1 foot. The lower member of the Otter Creek bed can be mapped only as far south as the township line. Coal was dug from the lower member in a pit just above the alluvium in the southwest corner of sec. 33. Along the south edge of the township the coal of the upper member is 2 feet 6½ inches thick at locality 58; nearby, at locality 59, the lower 1 foot 5 inches of the bed is exposed below till.

The Byer bed, 60 feet above the Otter Creek bed and present only on the east side of Otter Creek, formerly was mined in a large strip pit in sec. 5. To the south in sec. 8, at locality 62d, 3 feet 10 inches of coal was measured in a drill hole; to the east the coal was reported to be 2 to 5 feet thick at an abandoned mine in sec. 9. The only exposure

of the Byer bed south of sec. 9 is at locality 63, in sec. 22, where the coal is 2 feet 4½ inches thick and has a 4½-inch shale parting near the base. In sec. 35, coal has been mined in an open pit from a zone at the approximate level of the Byer bed.

A local bed 45 to 50 feet above the Otter Creek bed crops out in the township to the south and underlies a small area in sec. 32. The Red Butte bed, the highest coal stratigraphically in the township, is present only along the east edge of the area. At locality 64, on the road between secs. 1 and 2, an eroded section of the bed contains 1 foot 9 inches of oxidized coal. In the northern part of sec. 1, at locality 65d, a power auger drilled into 4 feet of coal in the Red Butte bed but did not penetrate to bed rock. The bed also is present in sec. 24, where 2 feet 4 inches of coal was measured at locality 66. The Red Butte bed could not be mapped west of this locality. A local bed 25 feet below the Red Butte was reported to contain about 2 feet of coal at an abandoned mine in sec. 25.

T. 142 N., R. 87 W. (FRACTIONAL)

(Plate 5)

All of T. 142 N., R. 87 W., except that part of the west row of sections west of logitude 101° 45′, lies within the Square Buttes coal field; the remainder is in the Knife River area. The Otter Creek–Brush Creek divide, which in places is as much as 350 feet above Otter Creek, extends generally north and south across the middle of the township. The west side of the divide slopes down gradually to Brush Creek, but the east side breaks off abruptly, giving way to rolling country cut by deep, narrow valleys. A northward-flowing tributary of Otter Creek drains the east side of the township and discharges into the creek in the northeast corner. A tributary of Beaver Creek, separated from Brush Creek by a low, rounded divide, drains the southwest corner of the township. This divide is notched at several places by former glacial diversion channels.

Strata of the Fort Union formation are the bedrock in this township. Wisconsin till covers about one-half of the area, glacial erratics remain on most of the surfaces stripped of till, and terrace remnants border all the large streams.

The Buckmann bed is concealed by alluvium and terrace deposits in the northern part of this township. The Herman bed, which is 25 to 30 feet above the Buckmann and stratigraphically the lowest coal exposed, contains only 1 foot 8 inches of coal at locality 25 in sec. 10, but it thickens to the south and east; at localities 26 and 27 it contains 2 feet 8 inches and 4 feet 2 inches of coal, respectively. Eastward from those localities the Herman bed thins rapidly and is only 1 foot thick in the adjoining township.

The Otter Creek bed, 35 feet above the Herman, is the most widespread and most extensively mined bed in the township. The bed consists of two members separated by 10 to 12 feet of shale. The lower member ranges in thickness from 3 to 4 feet. In the valley of the large tributary of Otter Creek along the east side of the township, the lower member could be mapped only as far south as locality 39 in sec. 24. From there southward the Otter Creek bed was mapped on the outcrop of the upper member which ranges in thickness from 2 feet 4 inches to 3 feet 8 inches except at localities 31, 33, and 35, where it contains less than 2 feet of coal.

A local bed 35 feet above the Otter Creek bed is 2 feet 6 inches thick at locality 40 in sec. 9 and at locality 41 in sec. 14. A local bed is present 70 feet above the Otter Creek bed in the central part of the township, but in the southeast it is only 55 feet above. At locality 42d, in sec. 21, drilling revealed 3 feet 6 inches of coal in this bed. North of that locality the coal is apparently replaced by carbonaceous shale. The coal can be traced to the south and east, however; and at locality 43, sec. 26, it is 2 feet 4 inches thick and has a 2-inch clay parting in the upper part of the bed. This bed was prospected in an open pit in the northern part of sec. 36, but the pit has since slumped in.

T. 143 N., R. 81 W. (FRACTIONAL)

Only a small part of T. 143 N., R. 81 W., lies west of the Missouri River in Oliver County. Alluvium and terrace remnants, ranging in width from about one-quarter to half a mile, cover most of this fractional township. In the southwest corner the land rises abruptly from the terraces to an upland 190 feet above the river.

The upper part of the Cannonball formation is exposed along streams that have cut below the level of the terraces. Beds in the lower part of the Fort Union formation crop out in the slopes below the upland. The contact between the Cannonball and Fort Union formations is exposed in the southwest corner of the township, but to the north is concealed under terrace deposits. Till covers most of the upland.

A thin coal about 70 feet above the base of the Fort Union was the only bed found in this partial township.

T. 143 N., R. 82 W.

(Plate 6)

Most of the drainage in T. 143 N., R. 82 W., is through a large unnamed creek that flows eastward across the middle of the township to the Missouri River, but small areas along the north and east margins drain through short tributaries directly into the river. That

part of the Missouri River valley in the northeast corner of the township is covered by terrace deposits. The side of the valley rises steeply from the terraces to an upland plain 140 to 175 feet above. An extensive network of former glacial diversion channels is present near the creek in the middle of the township; many of these channels contain underfit streams, which are tributaries of the creek. Many undrained depressions cover the upland plain. The maximum relief in the township is about 550 feet.

Rocks in the upper part of the Cannonball formation crop out in the valleys and under the terraces along the east side of the township. The rest of the area is underlain by the rocks of the Fort Union formation. The contact between the Cannonball and Fort Union formations is exposed poorly along the stream valleys and is covered by terrace deposits in the northeast corner. Till of Wisconsin age covers most of the surface of the township. Only on the steeper slopes leading to the upland and in the dissected areas along the larger streams has the till been removed by erosion. Some of the channels are floored with deposits of glacial diversion channel fill. Deposits of glacial outwash are found adjacent to some of the diversion channels.

Three small beds that make up a zone of coal, the base of which is 115 feet above the base of the Fort Union formation, crop out in the northeast quarter of the township. These beds are extremely variable in thickness and are mappable at only a few places. At locality 182, in sec. 12, all except the lowest bed are exposed fully. The 3 feet of coal in the upper bed is underlain by 12 feet 3 inches of shale and clay; the middle bed consists of 2 feet 8 inches of coal with a 3-inch clay parting; the upper 1 foot of the lowest bed is exposed below a shale parting 11 feet 7 inches thick. To the east, at locality 181, a complete section of the lowest bed contains 2 feet 10 inches of coal. The middle bed in the coal zone thins rapidly eastward from locality 182 and is only 1 foot 1 inch thick near the center of sec. 12.

A local bed 170 feet above the base of the Fort Union formation has been mined at several points in secs. 9 and 10. At locality 183, in sec. 9, the coal is 3 feet 4 inches thick. Smith (1909, p. 21) reported that this bed contains 5 feet of clean, hard lignite at the two mines immediately northeast of locality 183. He also stated that the coal is 6 feet 4 inches thick at a mine in the SE¼ sec. 10 which the writers could not locate; Smith may have been referring to the mine in the southwest quarter of the section. This local bed is present in only a small area in the north-central part of the township. A coal reported to be about 2 feet thick is found in a large spring in the NW¼ sec. 28; this is in an uncorrelated bed.

T. 143 N., R. 83 W.

(Plate 6)

The Missouri River flows eastward across a small area on the north edge of T. 143 N., R. 83 W. The gently rolling terrain of this township is broken on the north by the 100- to 160-foot escarpment forming the south side of the Missouri valley, and is trenched by the deep, narrow, steep-sided valleys of Mandan Lake Creek and other tributaries of the Missouri. The highest point on the Missouri River–Square Butte Creek divide, which crosses the southwest quarter of the township, is about 615 feet above the river.

About 500 feet of the Fort Union formation crops out in this township; the beds are well exposed in the deep valleys in the northern part. Most of the gently sloping surface north and east of the Missouri River–Square Butte Creek divide is mantled with till; south and west of the divide the till is patchy. Glacial diversion channel deposits of Wisconsin age fill a broad channel in the southwest quarter.

A local bed 110 feet below the Brazda bed is stratigraphically the lowest mappable coal that crops out in this area. The coal is 2 feet 1 inch thick in sec. 3 at locality 150, on the road along the river and thins westward to less than 2 feet. This local bed has been mined in two pits in sec. 2 on the east side of the valley of Mandan Lake Creek, where, according to Smith (1909, p. 22), the coal is 4 feet 4 inches thick with a 2-inch parting 4 inches from the bottom. Near the mouth of Mandan Lake Creek this bed contains 4 feet of carbonaceous shale.

A bed 80 feet below the Brazda coal is present in the rough country in the northern part of the township, but the coal is of mappable thickness in only a few places. At locality 151, in sec. 8, this bed contains 1 foot 1 inch of coal underlain by 4 feet 4 inches of sandy shale, below which is 2 feet 2 inches of coal. A short distance to the north, at locality 152, all except 6 inches of the upper coal has been removed by erosion; the interval between the two coals is 5 feet 1 inch; and the lower coal is 3 feet 1 inch thick. Northeast of locality 152 the lower coal thins rapidly to less than 2 feet except at locality 153, where it is 2 feet 2 inches thick. Along the valley of Mandan Lake Creek this local bed ranges in thickness from 2 feet 2 inches at locality 155 to 2 feet 7 inches at locality 154. A bed of lignite, tentatively correlated with this bed was reported by Smith (1909, p. 22) to be at least 2 feet 6 inches thick in the NE¼ sec. 3.

The Brazda bed crops out in the deep valleys in the northwest quarter of the township and in the valley of Mandan Lake Creek. The bed contains less than 2 feet of coal in the northwest corner but

thickens rapidly eastward to 3 feet 6 inches at locality 156 in sec. 8. Smith (1909, p. 22), who measured 3 feet 10 inches of hard coal at this locality, stated that the bed is 3 feet 9 inches thick in a mine near the middle of sec. 9. The only mine in sec. 9 is on the overlying Stanton bed; so it seems probable that he measured the thickness of the Stanton rather than the Brazda. The Brazda bed gradually thins eastward, and at locality 158, in sec. 14, it contains 2 feet 4 inches of coal.

The Stanton coal, which is 30 feet above the Brazda, crops out in the northwest quarter of the township, where it ranges in thickness from 1 foot 6 inches in a small area in secs. 8 and 9, between localities 162 and 163, to 4 feet 1 inch at locality 160.

The Yeager bed is present in the deep valley that trends northward through secs. 17, 8, and 5. At locality 164, erosion has removed all except 2 feet 1 inch of coal from this bed. At locality 165, in sec. 17, the Yeager is split into two beds separated by 13 feet 8 inches of shale and sandstone; the upper and lower beds are 2 feet 3 inches and 2 feet 2 inches thick, respectively. The Yeager bed thins northward; about three-quarters of a mile from locality 165 it contains only 1 foot 4 inches of coal.

The Hagel bed, which contains the thickest coal in the township, has been stripped in several large pits in sec. 20; the mine at locality 167 has 6 feet 2 inches of good coal; to the east, at locality 168, the upper 5 feet 5 inches of the bed is exposed. The landowner reported that the Hagel coal is about 5 feet thick in the old mine in the SW¼ sec. 17. A power auger drilled through 6 feet 8 inches of coal with a 4-inch parting near the middle at locality 166d in the northwest corner of sec. 30.

A coal zone, probably composed of several thin, discontinuous beds, was found 90 to 110 feet above the Hagel bed. A local bed at the base of this zone contains 2 feet 2 inches of coal at locality 169 in sec. 19. About half a mile to the southwest the bed is 1 foot 10 inches thick. Coal, reported to range in thickness from 2 to 4 feet, has been mined from this zone at small pits in secs. 21, 28, 32, and 33. A local bed 35 feet above the Red Butte bed underlies a small area on the high stream divide in sec. 31; the coal is not exposed.

T. 143 N., R. 84 W.

(Plate 6)

The gently rolling upland in the northern and eastern parts of T. 143 N., R. 84 W., has been deeply and intricately dissected by Alderin Creek and other tributaries of the Missouri River. The Missouri River–Square Butte Creek divide runs generally east and west across the south half of the township. On the east side of the

township the north slope of the divide is steep and rises rather abruptly from the upland; on the west, the slope is more gentle. The divide is trenched at two points by deep glacial diversion channels, the largest of which forms a long, broad valley in the southwest quarter of the township. Terraces border the Missouri River in the northeast corner of the area. The maximum relief from the area near the river to the highest point on the Missouri River–Square Butte Creek divide in sec. 35 is about 600 feet.

Rocks of the Fort Union formation underlie all the township; they are well exposed in the deeply dissected area in the eastern and northeastern parts and on the steep north side of the Missouri River–Square Butte Creek divide. Till, probably of late Wisconsin (Mankato) age, covers most of the gentle slopes. Diversion channel deposits floor the large channel in the southwest quarter of the township, and alluvium fills most of the larger stream valleys.

The Brazda bed, which is stratigraphically the lowest mappable coal, crops out in the deep stream valleys in the north-central and northeastern parts of the township. At locality 101, in sec. 4, the bed contains 3 feet 1 inch of coal broken by 3 feet 2 inches of carbonaceous shale; about half a mile to the northeast, at locality 102, only 1 foot 11 inches of the bed is exposed. To the south in sec. 9, locality 103, the Brazda bed is 2 feet 5 inches thick. Along the east side of the township the bed decreases in thickness northward from 3 feet 2 inches at locality 104, sec. 13, to 1 foot 8 inches at locality 107 in sec. 1. The coal exposed at locality 105, in sec. 12, is about 10 feet below the general level of the Brazda bed.

The clinker of the Stanton bed, which is 20 to 45 feet above the Brazda, is a conspicuous feature of the rough country in the northwest quarter. The maximum thickness of the bed, measured in a strip pit in sec. 4, locality 108, is 3 feet 11 inches. To the south at locality 109, in sec. 9, the Stanton contains 2 feet 1 inch of coal, but perhaps only the upper part of the bed is exposed there. In that same section, at locality 110, an incomplete exposure of the bed discloses 3 feet 5 inches of coal with a 5-inch carbonaceous shale parting. The Stanton bed thins to the east to 1 foot 8 inches and 1 foot 7 inches of coal at localities 111 and 112, respectively. In an old strip pit along the large stream in sec. 24, locality 113, 2 feet of the Stanton coal is exposed. Along the east boundary of the area in sec. 12, locality 114, the bed contains 2 feet 4 inches of coal.

The local bed that forms a conspicuous clinker 20 feet above the Stanton in the township to the north is present along the north edge of sec. 5 where a badly slumped section containing 10 inches of hard coal was observed.

The Berg bed, 40 feet above the Stanton, is clinkered at many points in the northwestern and central parts of the township. At an abandoned strip pit in sec. 7, locality 115, 6 feet 6 inches of coal is exposed. The coal thins eastward; in sec. 9 at localities 116 and 117, it is 4 feet and 3 feet 4 inches thick, respectively; a thin shale parting occurs just above the base of the coal in both exposures. The Berg bed thins to 1 foot 6 inches at locality 118 in the southern part of sec. 9, but at locality 119, sec. 16, just over the stream divide to the south, 3 feet 8 inches is present. A partial section of the bed, containing 4 feet of coal, is exposed at locality 120 in an old strip pit in the southeast corner of sec. 22. Coal formerly was mined in a shallow strip pit on the east side of sec. 23 from a thin bed that was correlated with the Berg bed.

The Yeager bed, traceable across most of the area north of the Missouri River–Square Butte Creek divide, is clinkered at scattered points in the valley of Alderin Creek in the northwest corner and at several places on the east side of the township. At locality 121, in sec. 7, there is 2 feet 9 inches of coal with an 8-inch carbonaceous shale parting in the upper half of the bed. Partial sections of the bed were measured at localities 122 and 123 where the coal is 3 feet 6 inches and 2 feet 8 inches thick, respectively. The best exposure of this bed, in the old Yeager mine, locality 124, sec. 21, exhibits two beds separated by 8 feet 5 inches of sandy shale. The upper bed is 5 feet 2 inches thick, including two thin partings; the lower contains 6 feet of clean coal. Coal has also been mined from this bed at two strip pits nearby. The Yeager bed is difficult to trace eastward from the Yeager mine across the broad, till-covered stream divides in the east-central part of the township. Near the abandoned mine in the NE¼ sec. 27, 1 foot 6 inches of badly weathered coal was uncovered in this bed, and at locality 125, on the road between secs. 14 and 23, the coal is 2 feet 2 inches thick. There is a 25- to 40-foot interval between the Yeager bed and the overlying Hagel bed which could not be found in outcrop but which could be traced by small patches of clinker from the east into the southeast quarter of the township.

The unexposed Kuether bed, about 50 feet above the Hagel, underlies an area adjacent to the large glacial diversion channel in the southwest quarter of the township. Small patches of clinker on the township line in sec. 32 indicate the horizon of the bed.

A bed correlated with the Red Butte bed crops out in secs. 26, 27, 34, 35, and 36. A hole drilled in this bed at locality 126d, sec. 35, disclosed 5 feet of coal containing two shale partings, 6 and 9 inches thick. Coal 1 foot 3 inches to 1 foot 11 inches thick has been mined in a small strip pit in the SW¼ sec. 21 from an unmappable bed about 30 feet below the Red Butte bed. Very thin beds of silicified shale are

associated with this bed which forms a distinct unit that is traced easily along the north slope of the Missouri River–Square Butte Creek divide. A local bed 35 feet above the Red Butte bed crops out on the Missouri River–Square Butte Creek divide in the southeast quarter of the township where, at locality 127d, sec. 35, a drill penetrated 3 feet of coal.

T. 143 N., R. 85 W.

(Plate 6)

The northern and western parts of T. 143 N., R. 85 W., drain through Kinneman Creek and tributaries of Brady Creek into the Knife River; the east side drains through Alderin Creek to the Missouri; and the southern part is in the Square Butte Creek drainage basin. The terrain in the north half of the township is low and is dotted with undrained depressions and criss-crossed with shallow diversion channels. The divides at the head of the Square Butte Creek drainage basin, however, are high and, in places, steep. The maximum relief in the township is about 400 feet.

The only exposures of the Fort Union formation are along the stream divides in the southern part of the township and in the rough country adjacent to Alderin Creek in the northeast corner. Till mantles the low country in the north, and extensive deposits of channel fill are present in most of the diversion channels.

The Yeager bed probably is present along Alderin Creek, but it does not crop out. The Kuether bed is present along the south boundary of the township in secs. 34, 35, and 36, but its outcrop is concealed by alluvium.

A local bed 60 feet below the Red Butte bed crops out in secs. 7, 8, and 18; drilling near an old mine, in sec. 7, locality 75d, disclosed 4 feet of coal. A local bed 35 feet below the Red Butte bed also crops out in the same general area. A drill penetrated 6 feet of clean coal in this bed at locality 76d, sec. 7, and 4 feet 10 inches at locality 77d, near an old pit in sec. 18. At locality 77d, the bed contains two 4-inch carbonaceous shale partings. This local bed thins eastward and is only 1 foot thick along the road between secs. 16 and 17.

The Red Butte bed crops out on either side of the Brady Creek–Kinneman Creek divide in the west-central part of the area and along the large diversion channel in the southwest quarter. A small mound of clinker in sec. 36 marks the horizon of the bed in the southeast corner. Coal has been mined from the Red Butte in underground workings in sec. 18, where a hole drilled southeast of the mine, locality 78d, disclosed 8 feet 1 inch of coal with a 5-inch parting just above the base of the bed. In a drill hole about one-half mile further southeast, locality 79d, the bed is only 6 feet thick and the lower 3

feet is interbedded shale and coal. The Red Butte was mined at two places in the southwest corner of the township: the drill penetrated 5 feet of clean coal at locality 80d near the abandoned drift mine in sec. 31, and a considerable amount of coal was mined in the strip pit just to the east in sec. 32 where the bed was reported to be about 4 feet thick. Some coal was dug also from a small mine in sec. 28.

A local bed 35 feet above the Red Butte bed was mapped along the Kinneman Creek–Square Butte Creek divide in the south-central part of the township. An exposure of the bed along Highway 25 in sec. 22, locality 82, shows 4 feet 11 inches of weathered coal; to the west it is 3 feet thick in a hole drilled in sec. 21, locality 81d.

T. 143 N., R. 86 W.

(Plate 6)

Brady Creek and tributaries of Otter Creek drain all of T. 143 N., R. 86 W., except the northeast corner which drains northeastward to Kinneman Creek. Brady Creek flows from the southeast corner to the north-central part of the township in a narrow valley, that becomes progressively more entrenched towards the north. The surface east of Brady Creek slopes gradually up to the low Brady Creek–Kinnenman Creek divide. The land west of Brady Creek rises quite abruptly to the Otter Creek–Brady Creek divide. That divide, which runs slightly northwestward across the middle of the township, is low and rounded along its northern end, but to the south becomes steeper and more rugged. Sandstone-capped knobs and ridges, the most prominent of which is Red Butte, in sec. 21, are scattered along the south half. The surface of the northwest quarter of the township is a gently rolling plain, that gradually slopes down towards Otter Creek. The area adjacent to the divide in the southwest quarter has been deeply dissected by tributaries of Otter Creek.

About 425 feet of the Fort Union formation underlies the surface of this township. The formation is exposed mainly along the stream valleys and on the higher, more rugged areas along the southern part of the Otter Creek–Brady Creek divide. Till of Wisconsin age covers all but the steeper slopes in the township. Exposures of the till are not readily apparent, because a large amount of eolian sand, blown in from the Knife River valley, is spread over much of the area.

The Beulah-Zap bed, which is formed of two members about 15 feet apart, crops out in the valley of Brady Creek. An incomplete section of the lower member at locality 48, sec. 4, contains 4 feet of coal. Although the lower member is concealed by alluvium upstream from locality 48, the upper member was traceable. At locality 49, sec. 9, the upper member has a thickness of 3 feet 4 inches.

A local bed about 30 feet below the Otter Creek bed crops out in the southwest corner of sec. 14, but the bed was not mapped because the coal is only 1 foot 9½ inches thick. Many years ago the coal was mined near the center of sec. 15.

The Otter Creek bed, 135 to 145 feet above the Beulah-Zap, is present along the west side of the township, and near the northeast corner. The Otter Creek consists of two members separated by 15 feet of shale along the west side, but the split was not recognized in the northeast corner. In sec. 19, locality 51, an incomplete section of the upper member contains 2 feet 2 inches of coal broken by a 2-inch shale parting near the base. To the north in sec. 18, locality 50, the lower member is 3 feet 3 inches thick; it is mined in an open pit. Because of the thick cover of sand and till, the Otter Creek bed could not be traced northward beyond sec. 7. This bed formerly was striped in sec. 2, and the workings of the large abandoned drift mine in sec. 35, T. 144 N., R. 86 W., may extend into this township. About 2 miles south of the strip mine the bed disappears and a sandstone is at its horizon.

The Byer bed, 65 feet above the Otter Creek, has been mined at several points in the southwestern, central, and northeastern parts of the township, but the writers found no exposures of the coal.

The Red Butte bed, which lies 135 feet above the Otter Creek bed, crops out along both sides of the Otter Creek–Brady Creek divide and in the southeastern quarter of the township. Under Red Butte the bed contains only 1 foot 2½ inches of coal, but it thickens to the south. On the west side of the divide at locality 52, sec. 33, the coal is more than 3 feet thick; the base is covered by water. Across the divide to the east at locality 53 the Red Butte bed is 5 feet thick; it was traced to the south and east into adjoining townships.

T. 143 N., R. 87 W. (FRACTIONAL)

(Plate 6)

All of T. 143 N., R. 87 W., in the northwest corner of Oliver County, lies within the Square Buttes coal field except that part of the west row of sections west of longitude 101°45′. Except for small areas in the northwest and southwest corners, the township is drained by northwestward-flowing Otter Creek. The land on the west side of the creek rises from the terraces bordering the stream to a high, rolling upland, the east edge of which is dissected by many deep stream valleys. The surface on the east side of Otter Creek slopes up gradually from the stream towards the divide with Brady Creek; several deep, steep-sided valleys cut this surface.

About 400 feet of the Fort Union formation is exposed in an irregular band 2 to 2½ miles wide along the west side of Otter Creek and along the streams that have trenched below the till-covered

surfaces. Wide gravel-covered terraces border Otter Creek and alluvium fills the valley.

A local bed 45 to 50 feet below the Spaer bed is stratigraphically the lowest coal bed mapped in this township. It crops out in the valley of Otter Creek and along a stream in sec. 5 where, at locality 3, the coal is 3 feet 1 inch thick. Along Otter Creek the bed is split into two members 15 feet apart. On the east side of the creek, in sec. 3, both members have been mined, but the coal is no longer exposed.

The outcrop of the Spaer bed, which is 45 feet below the Beulah-Zap, is extensive in this township. In sec. 3, at locality 6, the Spaer coal is unmappable but thickens rapidly southward; at locality 4, sec. 10, an eroded section of the bed shows 5 feet 8¼ inches of coal with two thin clay partings. The maximum thickness of the Spaer, measured at locality 5, sec. 22, is 7 feet 1 inch including a 4½-inch parting in the lower half of the bed. Abandoned mines on this bed in secs. 3, 5, 15, and 22 indicate that the Spaer probably is of minable thickness over a considerable area.

The Beulah-Zap bed, which contains most of the coal in this township, has been mined at many points along its outcrop, but the coal is exposed at only a few localities. In the adjacent Knife River area, the Beulah-Zap consists of two coals separated by 10½ feet of shale and sandstone, but in this township the split in the bed was recognized only in the northwest corner and at one locality in sec. 14 east of Otter Creek. At locality 7, sec. 5, the lower member has a thickness of 4 feet, the upper member contains only 11½ inches of coal, and the interval between the two members is 14 feet 3 inches. The thinness of the upper member is restricted; a short distance to the northeast at locality 8, sec. 5, the upper member is 2 feet 1 inch thick, and to the east at locality 9 it contains 2 feet 4 inches of coal. A small clinker mass about 15 feet below the outcropping coal probably marks the horizon of the lower member at locality 9. At localities 10, 11, and 12 the bed ranges in thickness from 2 feet ½ inch to 2 feet 7¼ inches. The true thickness of the Beulah-Zap is probably greater than at those localities, for the measurements were taken on weathered outcrops. An exposure of the bed at locality 13, along the line between secs. 2 and 3, shows 1 foot 11 inches of coal overlain by glacial till. In sec. 14 the Beulah-Zap is split into two beds about 15 feet apart; each is marked by an abandoned mine.

The Schoolhouse bed, 30 to 45 feet above the Beulah-Zap, was mapped only in the northwest quarter of the township where it is discontinuous and variable in thickness. The coal at locality 14, sec. 5, is 3 feet thick, but to the south and east of that locality it thins rapidly and within a short distance is unmappable. In the northwest corner of sec. 16 coal formerly was mined from the Schoolhouse bed.

In the southern part of that section the Schoolhouse thickens from 1 foot 11 inches at locality 15 to 2 feet 8½ inches at locality 16, but this thickening is local. An abandoned mine in the southeast quarter of sec. 14 marks the only known occurrence of the Schoolhouse bed on the east side of Otter Creek.

The Buckmann bed, which is 65 to 75 feet above the Beulah-Zap, is persistent in the southern part of the township but, because of the cover of till and vegetation, was difficult to trace in the northern one-third. At locality 17, sec. 21, the coal is 4 feet 5½ inches thick; it thins southward to only 1 foot 9 inches in secs. 28 and 33, but thickens again in the northwest corner of sec. 34 to 3 feet 2 inches of clean lignite. Coal is not exposed in the two abandoned mines on this bed in sec. 24 on the east side of Otter Creek.

The Herman bed, 25 to 30 feet above the Buckmann, is concealed by till at most places, but some measurements could be made. Exposures on the west side of Otter Creek show a thickness of more than 3 feet. At locality 21, sec. 29, an incomplete exposure shows a thickness of 10 feet 6 inches, but only the lower 4 feet 10 inches is suitable for mining, because the upper 5 feet 8 inches consist of interbedded shale and coal. To the southeast at locality 22, sec. 28, the coal is more than 4 feet 7½ inches thick, but contains two thin shale partings. Other coal sections were measured at localities 23 and 24 where the bed is 3 feet 2 inches and 3 feet 10 inches thick, respectively. The Herman bed was not mapped on the east side of Otter Creek, because it is only 15 inches thick at the abandoned mine in sec. 31, T. 143 N., R. 86 W.

The unexposed Otter Creek bed lies 135 feet above the Beulah-Zap; it was mapped in sec. 33 and along the east edge of the township by use of old mine locations.

T. 144 N., R. 81 W. (FRACTIONAL)

Only a very small part of T. 144 N., R. 81 W., is included in the Square Buttes coal field. All this fractional part is on the flood plain of the Missouri River, except a small area in the southwest corner of sec. 31 that is covered by terrace deposits only 5 to 10 feet higher than the river level.

The Cannonball formation underlies this area but is covered by alluvial deposits. The aluvium and terrace deposits are of Recent age.

T. 144 N., R. 82 W. (FRACTIONAL)

That part of T. 144 N., R. 82 W., south of the Missouri River is within the Square Buttes coal field. The Missouri here is bordered by a wide flood plain and extensive series of terraces, which together range in width from 1½ to almost 2¾ miles. The highest terrace in

the series is 120 feet above the river. In the southwest part of the township the valley side rises steeply behind the terraces 110 to 120 feet to a gently undulating upland. East of Hensler the upland is lower, and the break is much more gentle.

The upper part of the Cannonball formation underlies much of this township, but its only exposures are under terrace deposits in sec. 36. Rocks in the lower part of the Fort Union formation crop out in the steep slopes along the south side of the Missouri valley. Most of the upland surface is covered with till of late Wisconsin (Mankato) age; a hole drilled in sec. 30 penetrated 44 feet of the till without reaching bedrock. The extensive deposits of alluvium and terrace gravels are of Recent age, except the highest terrace remnants which may represent alluvial deposits laid down during the late Pleistocene.

Coal beds of mappable thickness were not found in this part of T. 144 N., R. 82 W., but several coal beds less than 1 foot thick crop out in the steep slopes below the upland surface; some coal was mined once in sec. 30 from one of those thin beds.

T. 144 N., R. 83 W. (FRACTIONAL)

(Plate 7)

That part of T. 144 N., R. 83 W., south of the Missouri River is within the Square Buttes coal field. The flood plain, 600 feet to almost 1½ miles wide, is bordered on the south by a series of terraces that are from 10 to about 125 feet higher than the river. Behind the terraces the valley wall rises abruptly to a high, rolling upland in the southeast corner of the township. Most of this fractional township drains into Mandan Lake Creek, which empties into the Missouri in the township to the east. Mandan Lake, a large marshy cutoff meander of the Missouri, lies along the course of the creek in secs. 27 and 34.

Beds of the Fort Union formation crop out along the side of the Missouri River valley and along the Mandan Lake Creek; rocks of the Cannonball formation that probably underlie part of this area are concealed by the Missouri alluvium; and till of Wisconsin age mantles the upland in the southeast corner of the township. The extensive deposits of alluvium and terrace material in the Missouri valley are the most conspicuous features in the area.

A local bed 110 feet below the Brazda bed is stratigraphically the lowest mappable coal in the township, but its outcrop is confined to a small area in sec. 34. Just south of the township line, at locality 150, the bed contains 2 feet 1 inch of coal. A local bed 80 feet below the Brazda bed was mapped for a short distance along Mandan Lake Creek and along the side of the Missouri River valley in sec. 35. At

locality 149 the coal is 3 feet 11 inches thick. A 2-inch shale parting occurs near the top of the bed. East of that locality the bed is concealed under grassy slopes.

T. 144 N., R. 84 W. (FRACTIONAL)

(Plate 7)

The only parts of T. 144 N., R. 84 W., within the Square Buttes coal field are the parts of secs. 31–36 south of latitude 47°15′ N. This fractional area is in Mercer County just north of the Oliver County line. Terrace remnants, ranging from 25 to 120 feet above the Missouri River, occupy most of secs. 35 and 36. Behind the terraces the country is characterized by deep and boxlike stream valleys and narrow and intricately dissected divides. All drainage is northeastward to the Missouri through Alderin Creek and other large streams.

Rocks of the Fort Union formation are well exposed in the rough country of this fractional township; erosional remnants of Wisconsin till remain in only a few areas along the stream divides.

The Brazda bed, 20 feet below the Stanton, crops out just above the alluvium along Alderin Creek. At locality 97, on the south edge of sec. 32, 2 feet 6 inches of the bed is exposed; the coal is overlain by gravel. The Brazda bed contains only 1 foot 7 inches of coal at locality 98 in sec. 34, but was reported to be about 2 feet thick in the abandoned mine on the south edge of that section.

Burning and clinkering of the Stanton bed along most of its outcrop in this fractional township precluded examination. The bed was reported to contain about 10 feet of coal in a mine on the south boundary of sec. 32, but the bed is now covered.

A local bed occurs 25 feet above the Stanton in this area, but at many places the clinker marking the bed's position merges with the Stanton clinker. At locality 99, on the road between secs. 32 and 33, this local bed contains 1 foot 10 inches of coal.

The horizon of the Berg bed, most of which is concealed by till, is marked by small clinkers on the north side of Alderin Creek in secs. 31 and 32. Apparently the Berg bed does not extend northward into the Knife River area.

The outcrop of the Yeager bed is confined to a small area along the north side of Alderin Creek; only 1 foot 10 inches of coal was measured at locality 100 in sec. 31. The bed was not traced northward into the Knife River area.

T. 144 N., R. 85 W. (FRACTIONAL)

Only that part of the south tier of sections of T. 144 N., R. 85 W., south of latitude 47° 15′ N. is within the Square Buttes coal field; the

rest is in the Knife River area. Gently rolling country of low relief is characteristic of this fractional township, but in sec. 36 the rolling surface breaks away abruptly to rough country bordering Alderin Creek. All but a small area in sec. 36 drains northwestward through Kinneman Creek to the Knife River.

The only exposures of the Fort Union formation are in the rough country in sec. 36 because most of the township is covered with a thick layer of Wisconsin till. The upper valley of Kinneman Creek contains an extensive deposit of glacial diversion channel fill.

Mappable coal beds do not crop out in this area, but a bed 1 foot 10 inches thick crops out in the rough country in sec. 36 and has been mined in a small pit in the northeast corner of that section. Coal also was mined from a small pit in sec. 31, but a hole drilled near that mine disclosed only interbedded shale and coal.

T. 144 N., R. 86 W. (FRACTIONAL)

(Plate 7)

That part of T. 144 N., R. 86 W., south of latitude 47° 15′ N., is in the Square Buttes coal field; this fractional part is in Mercer County. The rest of the township is included in the Knife River area. This fractional area is a gently undulating plain incised by Brady Creek and its tributaries. Brady Creek flows northward across the middle in a narrow valley about 85 feet deep.

Rocks of the Fort Union formation underlie this township but are exposed only in the stream valleys. Till of Wisconsin age covers all of the upland, but the till itself is concealed under a blanket of eolian sand except along streams and in road cuts.

Only two coal beds crop out in this area. The lowest bed, the Beulah-Zap, is present in the valley of Brady Creek and along its tributaries. At locality 46 the upper member of the Beulah-Zap contains 3 feet 7 inches of coal. The Otter Creek bed, 140 feet above the Beulah-Zap, is present on the upland east of Brady Creek; a power auger drilled through 7 feet of clean coal in this bed near the abandoned drift mine in sec. 35.

T. 144 N., R. 87 W. (FRACTIONAL)

(Plate 7)

Only those parts of secs. 31–36, T. 144 N., R. 87 W., south of latitude 47°15′ N. and east of longitude 101°45′, are in the Square Buttes coal field; the rest of the township is in the Knife River area. The surface of this fractional township is a gently rolling upland drained by Otter Creek and by streams that flow directly into the Knife River. Otter Creek flows northward across the middle of the area in a broad valley, the bottom of which is about 120 feet below the

general level of the upland, and discharges into the Knife River about one-fourth of a mile north of the coal field.

Rocks of the Fort Union formation crop out along the streams, most of the upland is mantled by Wisconsin till, but most of the till is hidden by a layer of eolian sand blown in from the adjoining Knife River valley. Some of the stream terraces in the Knife River valley extend into this area.

A local bed 85 to 90 feet below the Spaer bed is stratigraphically the lowest coal that crops out in this fraction of the township. This bed may be equivalent to the Hazen B bed in the Knife River area. At locality 1, sec. 32, the only outcrop of the bed contains 4 feet 5 inches of oxidized coal. A local bed 45 to 50 feet below the Spaer consists of two members separated by 15 feet of shale. In sec. 33, at locality 2, a partial section of the lower member in an old mine shows 3 feet 10 inches of coal. About 1 foot of coal in the upper member is exposed in an abandoned mine at the same locality. The Spaer and Beulah-Zap beds are present in this area, but their outcrop is concealed by till and vegetation.

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