UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey

PRELIMINARY GEOLOGIC MAP OF THE DENGATE QUADRANGLE, MORTON COUNTY, NORTH DAKOTA

By

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Open-file map

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INTRODUCTION

The Dengate quadrangle is an area of approximately 51 square miles in western Morton County, southwestern North Dakota. The quadrangle is about 40 miles west of Bismarck, the State capitol (fig. 1) and about 3.5 miles east of Glen Ullin (population 1,087). Interstate Highway 94, U.S. Highway 10, and the Northern Pacific Railroad cross the northern part of the area in an east-west direction.

The Dengate quadrangle is one of a group of 14 adjoining 7½-minute quadrangles (fig. 1) that are being mapped by the U.S. Geological Survey to furnish a basis for classification of lands withdrawn by the Federal Government pending classification for coal, and to contribute to the geologic map atlas of the United States. Most of the fieldwork for the Dengate quadrangle was done during the late summers and early autumns of 1965 and 1966.

During the summer of 1966, the U.S. Geological Survey conducted a drilling program in the Dengate and nearby quadrangles (Smith, 1970) to gather information on the existence, thickness, and depth of lignite beds in withdrawn Federal lands. Two of the holes drilled are in the Dengate quadrangle.

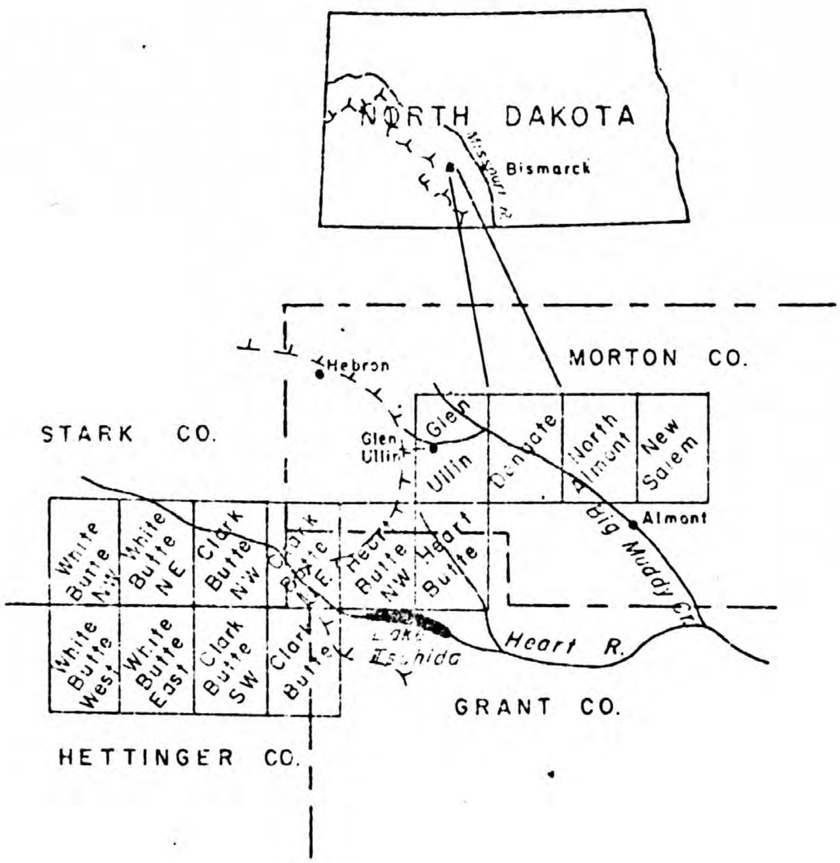

FIGURE 1.--Index map showing the location of the Dengate and other 7½-minute quadrangles in North Dakota being mapped by the U.S. Geological Survey. Hachured lines show the outermost drift border of the Wisconsinan Stage as mapped by Colton, Lemke, and Lindvall (1963).

PHYSIOGRAPHY

The Dengate quadrangle is in the Missouri Plateau section of the Great Plains physiographic province (Fenneman, 1931, p. 61). The area contains rolling prairies, numerous sandstone hills and buttes, the broad Curlew Valley, and steep-sided buttes in which lignite beds of the Fort Union Formation have burned and the overlying sediments have been baked to form a resistant rim or cap rock. Locally, dissection of clayey parts of the Fort Union Formation has produced badland topography.

The principal stream in the area is Big Muddy Creek, an underfit stream in the Curlew Valley which flows southeastward across the quadrangle and joins the Heart River, a tributary of the Missouri River, about 17 miles southeast of the quadrangle.

The climate of the area is semiarid. The winters are long and severe; the summers are short and hot.

Some of the area is under cultivation for grain, mostly wheat; the rest generally has a cover of prairie grass. Brush and deciduous trees grow along watercourses, and, less commonly, in small patches on some slopes in hilly terrain.

Outcrops in the Dengate quadrangle are few and generally poor; the best are in areas of badland topography.

STRATIGRAPHY

The Tongue River and Sentinel Butte Members of the Fort Union Formation of Paleocene age underlie most of the surface (pl. 1). The Fort Union is locally covered by Pleistocene glacial drift or Holocene alluvium. A generalized stratigraphic section of the Fort Union is presented on plate 2. Stratigraphic sections measured in the Fort Union in the quadrangle and nearby areas are shown graphically on plates 2 and 3.

Tertiary rocks

Fort Union Formation

The Paleocene Fort Union Formation in North Dakota consists of the Ludlow, Cannonball, Tongue River, and Sentinel Butte Members (Brown, 1962, p. 11). The Ludlow Shale Member, a continental deposit, is the basal unit of the Fort Union in southwestern North Dakota where it conformably overlies the Upper Cretaceous Hell Creek Formation; eastward toward the Missouri River it intertongues with the marine Cannonball Member (Brown, 1962, fig. 1). The Tongue River and the overlying Sentinel Butte are continental deposits and are exposed over most of western North Dakota (Carlson, 1969). In southwestern North Dakota the Sentinel Butte Member is locally conformably (Hickey, 1969, p. 100) overlain by the Golden Valley Formation (late Paleocene and Eocene) or unconformably by the White River Formation (Oligocene).

A total of about 445-495 feet of the Tongue River and Sentinel Butte Members of the Fort Union is exposed in the Dengate quadrangle. The base of the formation is in the subsurface; it was not reached in the holes drilled for the U.S. Geological Survey in 1966. The top was not found; it probably has been removed by erosion. The closest exposures of the base of the Fort Union, the contact between the Cannonball or Ludlow and the Hell Creek Formation, are about 20-25 miles southeast of the quadrangle in southeastern Morton County (Laird and Mitchell, 1942, pl. I; Carlson, 1969). The contact between the Golden Valley Formation and the Sentinel Butte Member is well exposed on Hasselbrad Butte (Benson, 1953, p. 82-83) and other high buttes a few miles west and north of Hebron, 15 miles west of Glen Ullin.

That part of the Fort Union Formation exposed in the Dengate quadrangle is composed of very thinly to thickly interbedded sandstone, siltstone, mudstone, and claystone and subordinate beds of carbonaceous shale and lignite and pods of limestone. Sandstone also occurs in very thick lenticular beds which locally cut out thick sections of the other rock types. Colors in the formation are generally light shades of gray, yellow, and olive and darker shades of gray, olive gray, and greenish gray. The sandstone is generally light colored, very fine grained, and silty. Sandstone in some very thick lenticular channel-filling deposits is mostly fine grained and is locally conglomeratic with rounded pebbles of claystone or siltstone and angular fragments of ferruginous nodules. The siltstone is generally clayey and is light or moderately dark colored, depending on the clay content. The claystone is commonly dark and silty. Silty claystone and clayey siltstone are the most abundant rock types in the formation. Mudstone is a term used for a massive rock that contains at least 50 percent clay and silt but in which the relative amounts of silt and clay are unknown. Brownish-gray to dark-grayish-brown carbonaceous claystone, mudstone, or shale is generally associated with lignite beds.

Limestone occurs in discoidal pods that are commonly 1-3 feet thick and 3-8 feet in diameter and weather yellowish orange. Lines of limestone pods crop out at several stratigraphic horizons in the Tongue River but are rare in the Sentinel Butte. A Tongue River limestone pod 1½-2 feet thick that crops out just above the ys marker bed near the C N½ sec. 15, T. 138 N., R. 87 W., was sampled and studied in detail. The pod is composed of dense brownish-gray limestone capped by a few inches of reddish-brown ferruginous silty limestone containing fragments of fossil mollusks, mostly snails. In thin section the limestone primarily consists of a groundmass of very fine grained calcite containing small scattered grains of quartz and iron oxide and much lesser amounts of feldspar, pyrite, chlorite, and mica. Samples from the lower part (D-10a-1, -2), upper part (D-10b, 10b-1), and top (D-10c-1, -2) of the pod and representative samples (D-16, D-48, and D-60) of three other limestone pod outcrops were analyzed for Ca, Mg, Fe, and Mn (table 1). Samples D-16 and D-48 are from about the same stratigraphic level as the D-10 series. Sample D-60 is from the upper part of the Sentinel Butte Member (strat. secs. 55 and 56, pl. 3). Samples D-48 and D-60 are petrographically similar to samples D-10a-1 and -2, D-10b, and D-10b-1. Sample D-16 contains more quartz and is better stratified than the other samples. Diffractograms of each of the samples show the 2.9 Å peak of dolomite. Sample D-16 contains at least 10 percent dolomite.

TABLE 1.--Ca, Mg, Fe, and Mn analyses of limestone pods in the Tongue River and Sentinel Butte Members, Fort Union Formation

[Analyses for Ca, Mg, and Fe by titration methods; for Mn by spectrophotometer. Results for Ca and Mg are accurate within ± 3 percent. Analyst: R. F. Gantnier, U.S. Geological Survey]

Sample No.	Acid soluble	Total carbonate	Ca (percent)	Mg (percent)	Fe (percent)	Mn (percent)	Ca/Mg (molal ratio)
D-10a-1	75.95	68.34	26.63	0.51	2.81	< 0.1	31.69
D-10a-2	76.25	70.09	27.23	.58	2.42	< .1	29.48
D-10b	76.30	69.95	26.73	.90	2.52	< .1	18.02
D-10b-1	75.55	71.27	27.62	.64	2.10	< .1	26.19
D-10c-1	63.40	54.50	21.09	.51	10.05	.2	25.10
D-10c-2	63.20	54.24	20.89	.58	9.35	.2	21.86
[1]D-16	71.15	62.25	23.33	1.13	2.14	.0	12.53
[2]D-48	80.70	74.64	28.90	.69	1.95	.0	25.42
[3]D-60	78.05	71.33	27.74	.57	1.57	.4	29.53

[1] From NE¼SW¼ sec. 16, T. 138 N., R. 87 W.

[2] From NW¼NW¼ sec. 34, T. 139 N., R. 87 W.

[3] From SW¼SW¼ sec. 18, T. 139 N., R. 87 W.

Carbonate is the predominant cementing material in most rocks other than claystone and some mudstone. Insoluble-residue analyses of 181 samples (54 from that part of the Tongue River above the ys marker bed and 127 from the Sentinel Butte) from outcrops of clastic rocks in the Glen Ullin and Dengate quadrangles were made by R. F. Gantnier, using approximately 4N HCl. The results of these determinations show that acid-soluble material ranges from 3 to 29 percent in about 90 percent of the samples and 31 to 76 percent in 10 percent of the samples. Samples containing more than 50 percent acid-soluble material are from resistant limy sandstone lenses. Thin sections of several such samples show extensive replacement of matrix material by calcite. In general, the formation is not well indurated and can be sampled with a digging tool. Exceptions are very limy lenses in sandstone, silicified carbonaceous rocks, limestone, and some slabby very woody lignite. In drill holes the hardest rocks encountered were limestone and very limy sandstone.

Pyrite in small (1 in. diameter) round balls, in larger nodules, and in irregular branching shapes occurs in most rock types but seems to be most common in carbonaceous shale and lignite and near the top of sandstone beds overlain by carbonaceous shale or lignite. Crystals and very thin lenticles of fibrous gypsum locally occur in carbonaceous rocks and lignite. Barite crystals in a fibrous aggregate 3 by 6 inches in cross section were found in a carbonaceous clayey siltstone core from a depth of about 225.5 feet in the drill hole in sec. 18, T. 139 N., R. 87 W.

Locally resistant ferruginous layers generally about 1 inch thick form dark-yellowish-orange bands in some exposures of claystone-siltstone and, less commonly, in clayey laminae in sandstone. These ferruginous layers are believed to be the weathered counterparts of beds composed of yellow very limy claystone enclosing a commonly pyritic limestone core which were seen in samples from U.S. Geological Survey drill holes.

Fossil animal and plant material is locally abundant but generally fragmental. Well-preserved snail and clam shells appear to be most numerous in the lower part of the formation. Carbonized rootlets and wood fragments are common in carbonaceous rocks. Some fine-grained rocks contain impressions of leaves and stems. White-weathering petrified stumps and wood fragments locally occur in some carbonaceous shale and lignite beds in the upper part of the formation.

Tongue River Member

About 180-220 feet of the upper part of the Tongue River is exposed in the Dengate quadrangle. Along part of the Heart River valley in northern Grant County 15-20 miles south of Glen Ullin, Tisdale (1941, p. 10-11, pl. 1) mapped the contact between the Cannonball and Tongue River Members of the Fort Union and reported that the Tongue River commonly has a basal sandstone as much as 100 feet thick. Using Tisdale's thickness for the basal sandstone and the stratigraphic interval between the top of the basal sandstone and various Fort Union marker beds which also crop out in the Dengate quadrangle, the total thickness of the Tongue River in the quadrangle is estimated to be at least 295-325 feet.

Reconnaissance by the author and mapping by others (Tisdale, 1941; Stephens, 1970a, b) suggest that in the region between the southern part of the Dengate quadrangle and the Heart River and between the town of Almont and Lake Tschida (fig. 1) the Tongue River Member can locally be divided into two parts informally designated units A and B. The lower part, unit A, is estimated to be at least 150-210 feet thick regionally and 150-180 feet thick in most places in the Dengate quadrangle. It consists of thick light-colored lenticular sandstone beds, dark-colored mudstone and claystone, and a few lignite beds. The base of the Tongue River was not seen in the region reconnoitered, and only a portion of the upper part of unit A is exposed in the quadrangle.

Near the east end of the north shore of Lake Tschida on the Heart River, the sandstone that Tisdale (1941, p. 10-11) referred to as the basal sandstone of the Tongue River forms a light-gray to light-yellowish-gray cliff and is about 185 feet below the top of the Tongue River Member. The tops of thick sandstone beds that occur in the lower part of unit A and near the stratigraphic level of Tisdale's (p. 10-12) sandstone of the Lake Tschida area are about 245, 220, 195, and 210 feet below the top of the Tongue River in drill holes in sec. 28, T. 138 N., R. 88 W., Heart Butte quadrangle (Stephens, 1970b); in sec. 32, T. 139 N., R. 88 W., Glen Ullin quadrangle (Barclay, 1970, pl. 3); in sec. 20, T. 138 N., R. 87 W., Dengate quadrangle; and in sec. 18, T. 139 N., R. 87 W., Dengate quadrangle, respectively. A sandstone outcrop along a stream bank near the center sec. 14, T. 137 N., R. 86 W., south of Almont, is the top of a sandstone that is also in the lower part of unit A and near the position of Tisdale's basal sandstone. A stratigraphic section of the outcrop is shown on plate 2.

Thick mudstone and subordinate claystone beds which characteristically have very somber outcrop colors, mostly dark olive gray and brownish gray, generally occur in the upper part of unit A. The most extensive outcrops of these somber beds are south of Almont in those parts of T. 137 N., Rs. 85 and 86 W., that are west of Big Muddy Creek and at altitudes between 1,900 and 2,100 feet. Stratigraphic sections of some of these outcrops are shown on plate 2. Drab sandy shaly mudstone beds near the top of unit A are exposed on the northeast bank of Big Muddy Creek in sec. 3, T. 138 N., R. 87 W., Dengate quadrangle (strat. sec. 33, pl. 2), and on the northeast side of Heart Butte Creek in secs. 27 and 34, T. 137 N., R. 88 W., Heart Butte quadrangle.

Lignite beds that can be used in some areas as stratigraphic markers commonly occur in the upper part of unit A. On the north side of Lake Tschida a thick lignite bed with a thin mollusk coquina bed above is locally well exposed just above the top of the basal sandstone, and in the same general area another lignite bed crops out about 71 feet above the basal sandstone (Tisdale, 1941, p. 11-13). The lower of these beds was mapped by Stephens (1970a, b) as the Shell lignite bed; the upper one appears to be correlative to a bed that is at the top of unit A, 42-62 feet above the Shell lignite, and which Stephens (1970a, b) mapped as the Koehler lignite bed. A thin lignite or carbonaceous shale bed that locally has a very thin coquina of snail and small clam shells in the roof claystone commonly occurs at the top of unit A south of Almont in T. 137 N., Rs. 85 and 86 W., where it appears to be what Hancock (1921, p. 32, 35, pl. V) mapped as the B bed. A similar bed at the top of unit A was mapped in the Dengate quadrangle as the ys marker and was traced into the North Almont quadrangle where it is what H. L. Smith (oral commun., May 20, 1971) in the W½ sec. 4, T. 138 N., R. 86 W., calls the Crooked Creek bed.

At an altitude of about 2,095 feet on a hill on the east side of Sims Creek in the NE¼ sec. 14, T. 138 N., R. 86 W., New Salem quadrangle, rocks typical of the basal part of unit B rest on a thin lignite bed that is probably equivalent to the ys marker and that Hancock (1921, pl. V) appeared to map as his B bed. According to Hancock (p. 13) the B bed is generally about 55 feet above his A bed, which may be equivalent to Stephens' (1970a, b)

Shell lignite. Hancock (p. 13) put his A bed about 45 feet above the top of the Cannonball, but in the area that he mapped south of Almont he may have included some sandstone near the base of the Tongue River in the Cannonball.

Identification of the ys marker bed or especially of the Shell lignite bed is difficult in the subsurface except where outcrops of the beds are close. The ys marker bed was intersected about 96.5 feet below the top of the Tongue River in the drill hole in sec. 20, T. 138 N., R. 87 W., and about 145 feet below the top in the drill hole in sec. 18, T. 139 N., R. 87 W. The lignite bed that Stephens (1970b) showed about 160 feet below the top of the Tongue River in the drill hole in sec. 28, T. 138 N., R. 88 W., Heart Butte quadrangle, may be equivalent to the ys marker bed of the Dengate quadrangle. A thin lignite 220 feet below the top of the Tongue River in the drill hole in sec. 32, T. 139 N., R. 88 W., Glen Ullin quadrangle (Barclay, 1970, pl. 3) and the lowest lignite bed in each of the drill holes in the Dengate quadrangle (pls. 2, 3, this report) overlie thick sandstone beds in the lower part of unit A, and any one or all of them may be approximately equivalent to Stephens' (1970a, b) Shell lignite.

In many places the dark-colored fine-grained rocks typical of the upper part of unit A are largely replaced by thick lenticular sandstone beds. In the Lake Tschida area, Tisdale (1941, p. 12) reported 42 feet of sandstone about 30 feet above the basal sandstone. A massive sandstone more than 40 feet thick that contains some very thin siltstone or mudstone beds near the top crops out in this interval on the north side of Scab Creek in the SE¼NW¼ sec. 23, T. 138 N., R. 87 W., in the southeastern part of the Dengate quadrangle. A thick sandstone sequence in the upper part of unit A is well exposed in the bluffs bordering Curlew Valley just south of Almont and is probably the sandstone that Hennen (1943, p. 1580) identified as the Almont sandstone and mistakenly correlated with the basal sandstone of the Tongue River. Thick sandstone beds were also encountered in approximately the same interval in holes drilled for the U.S. Geological Survey in sec. 28, T. 138 N., R. 88 W., Heart Butte quadrangle (Stephens, 1970b), in sec. 32, T. 139 N., R. 88 W., Glen Ullin quadrangle (Barclay, 1970, pl. 3), and in sec. 18, T. 139 N., R. 87 W., and sec. 20, T. 138 N., R. 87 W., Dengate quadrangle.

Unit B of the Tongue River Member is about 95-160 feet thick in the Dengate quadrangle and consists of a lower sequence of clayey siltstone, mudstone, and subordinate sandstone and an upper sequence of siltstone and sandstone. The lower part of unit B is commonly about 80 feet thick, although the range in thickness is from about 45 to 115 feet. It is marked at the base by a pale-yellow or golden zone, commonly 20-30 feet thick, of locally fossiliferous clayey siltstone that contains thin ripple-marked sandstone beds and locally fossiliferous limestone pods. Fossil materials are snails and small clams and, in the clayey siltstone, numerous plant remains. This distinctive basal interval is prominently displayed south of Almont on some of the buttes in T. 137 N., Rs. 85 and 86 W., where it is in sharp color contrast to the drab beds of the underlying unit A. The yellow zone can be recognized in outcrops in the Heart Butte, Heart Butte NW, Dengate, North Almont, and New Salem quadrangles.

The Tavis Creek lignite bed (TC), which ranges in thickness from less than 2 to more than 5 feet and locally appears to split into two beds as much as 20 feet apart, occurs at the top of the lower part of unit B. It can be traced into the adjacent Glen Ullin (Barclay, 1970, p. 7, 15) and North Almont quadrangles. The Tavis Creek bed is equivalent to the bed at Klondike Butte in the New Salem quadrangle that H. L. Smith (unpub. map, U.S. Geological Survey) mapped as the Cut Bank Creek bed and to Stephens' (1970a, b) Beaver Creek bed in the Heart Butte and Heart Butte NW quadrangles. It also appears to be equivalent to Hancock's (1921, p. 13) C bed of the New Salem area. The interval between the basal pale-yellow unit of rocks and the Tavis Creek bed consists generally of olive-gray to pale-olive clayey siltstone and mudstone and subordinate light-olive-gray to yellowish-gray sandstone, at least one horizon of limestone pods, and a few thin lignite beds. Thick lenticular channel-filling sandstone beds are locally present in the lower part of unit B. Very thick sandstone bodies that appear to be of this type and at this stratigraphic level crop out in the southeastern part of the Dengate quadrangle and along Heart Butte Creek in the southern part of the Heart Butte quadrangle, and, according to a lithologic log prepared by Stephens (1970b), occur in the interval 95-120 feet below the top of the Tongue River in a drill hole in sec. 28, T. 138 N., R. 88 W., Heart Butte quadrangle.

The upper part of unit B of the Tongue River ranges in thickness from 10 to 40 feet but is generally about 20-30 feet thick. It is locally well exposed and is composed predominantly of dusky-yellow clayey siltstone and yellowish-gray sandstone. Limestone pods crop out in the upper part. Olive-gray to pale-olive silty claystone is present at the base; similar rocks at the top are capped by a thin carbonaceous layer. This carbonaceous layer is commonly less than 1 inch of lignitic carbonaceous shale, but in some places it is locally a lignite bed more than 6 inches thick which contains white-weathering silicified wood slabs and large tree stumps. In western North Dakota a lignite bed referred to as the HT Butte lignite, locally more than 10 feet thick (Royse, 1967, p. 5), occurs at the top of the Tongue River.

Fossil snails and clams were collected from the upper part of unit A and from the distinctive pale-yellow interval of rocks at the base of unit B for age assignment and paleoecological interpretation. At USGS Cenozoic locality D24512 near the north shore of Lake Tschida in the Heart Butte NW quadrangle fossil snails collected from clayey siltstone beds 25-30 feet below the top of Stephens' (1970a) Koehler bed (ys marker equivalent) were identified as *Campeloma nebrascensis* (Meek and Hayden) and *Lioplacodes nebrascensis* (Meek and Hayden) by N. F. Sohl of the U.S. Geological Survey (written commun., April 10, 1968). At USGS Cenozoic locality M2704 (strat. sec. 33, pl. 2) fossils collected about 27 feet below the top of a lignite mapped as the ys(?) marker were identified as the clam "*Corbula*" *mactriformis* Meek and Hayden and the snails *Campeloma nebrascensis* (Meek and Hayden) and *Cleopatra tenuicarinata* (Meek and Hayden) by D. W. Taylor of the U.S. Geological Survey (written commun., Aug. 15, 1966). At USGS Cenozoic locality M2702 (strat. sec. 33, pl. 2) fossil snails collected about 4.5 feet above the ys(?) marker were identified by Taylor (Aug. 15, 1966) as *Bellamya leai* (Meek and Hayden), *Bellamya* sp., and *Campeloma nebrascensis* (Meek and Hayden). A collection from USGS Cenozoic locality M2721 (strat. sec. 4, pl. 2) at about the same stratigraphic level as M2702 consisted of the clam *Corbula* cf. *C. crassatelliformis* Meek and *Campeloma nebrascensis* (Meek and Hayden) (D. W. Taylor, written commun., Aug. 22, 1966). Taylor (Aug. 15 and 22, 1966) described all the fossils that he identified as fresh-water middle Paleocene forms, although he also suggested that *Corbula* cf. *C.*

crassatelliformis (Meek and Hayden) may have tolerated both brackish and fresh water. W. A. Cobban (oral commun., May 4, 1971) believed that *Corbula* and its relatives were estuarine animals.

Samples of carbonaceous rocks in core recovered from holes drilled in the Sentinel Butte and Tongue River Members in sec. 18, T. 139 N., R. 87 W., and in sec. 20, T. 138 N., R. 87 W., were collected for palynological correlations of lithologic units mapped in the field. R. H. Tschudy of the U.S. Geological Survey (written commun., June 26, 1968), after a detailed qualitative and quantitative palynological study of the samples, made the following observations:

> "1. The species comprising the microfossil flora show few qualitative changes in the Tongue River and Sentinel Butte.
>
> "2. Prominent quantitative changes are observed at successive levels in each well.
>
> "3. These maxima and minima, or levels of abundance or lack of abundance, can be correlated between the two wells [fig. 2].
>
> "4. These correlation horizons parallel the lithologic boundaries separating the several members [Sentinel Butte, Tongue River, and units A and B of the Tongue River] of the Upper Fort Union Formation.
>
> "5. The events causing the floral changes affected the floras surrounding the original deposition sites simultaneously; the correlation horizons may be considered as time-lines."

Tschudy (written commun., Dec. 16, 1966, June 26, 1968) also reported that a high percentage of Taxodiaceous-Cupressaceous pollen was found in an outcrop sample of the lower part of a lignite bed locally mapped as the ys marker (D3818-B, strat. sec. 10, pl. 2) and in all core samples.

Stratigraphically, the lowest sample collected in the Dengate quadrangle is D4494 from the drill hole in sec. 20, T. 138 N., R. 87 W. According to R. H. Tschudy (written commun., July 15, 1970) it contains a pollen assemblage that suggests a lower (but not lowermost) or middle Paleocene age, a Lebo (but not Tullock) equivalent age. Tongue River rocks older than this have been found nearby in the northeastern part of the New Salem lignite field by Leffingwell (1971, p. 17) who reported that a sample from Hancock's (1921, pl. V) A lignite contains a Tullock-basal Lebo Shale palynological assemblage, an assemblage characterized in part by the highest appearance of *Kurtzipites* (R. H. Tschudy, oral commun., 1970; Leffingwell, 1971, p. 14).

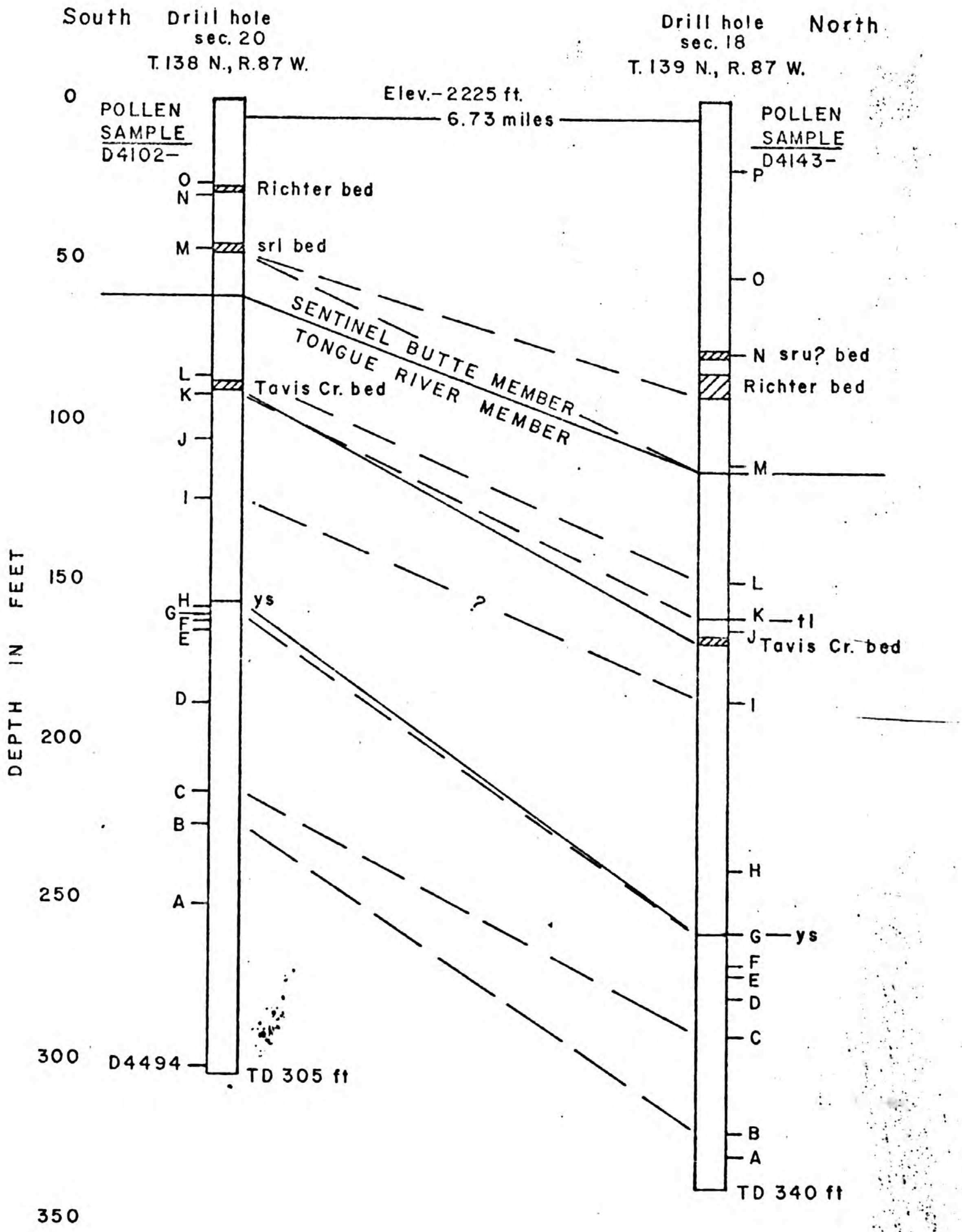

FIGURE 2.--Chart showing palynological correlations of core samples of Fort Union rocks encountered in two drill holes in the Dengate quadrangle, Morton County, N. Dak. Modified from R. H. Tschudy (unpub. data).

The exact stratigraphic position of the bed that Leffingwell sampled is unknown. Hancock's (1921, p. 13) B bed is equivalent to the ys marker, and his A bed, which he describes as generally being about 55 feet below B, should occur above sample D4494. It may be that the bed that Leffingwell sampled is not the bed that Hancock mapped as the A bed in other parts of the New Salem area but is a much lower bed. According to G. D. Mowat of the U.S. Geological Survey (oral commun., June 1971), the highest occurrence of Kurtzipites found by Tschudy (written commun., Aug. 31, 1967) in samples from a drill hole in the NW¼NW¼NE¼ sec. 29, T. 137 N., R. 90 W., Clark Butte NE quadrangle, Grant County, N. Dak., is 417-422 feet below the top of the Shell lignite.

Sentinel Butte Member

The Sentinel Butte Member, which is about 265-285 feet thick in the Dengate quadrangle, is lithologically similar to the Tongue River Member. Separation of the two members in the field, based primarily on a change from light outcrop colors below to drab outcrop colors above, is difficult except in those areas where considerable distances across the contact are exposed. The color separation and other features that may be used in differentiating between the two members in western North Dakota were ably discussed by Royse (1967, 1970).

In the Dengate quadrangle the Sentinel Butte Member is characterized by drab-colored bentonitic mudstone and clayey siltstone beds, locally abundant white-weathering silicified carbonaceous shale, stumps, and logs, and the "mud butte" topography described by Seager and others (1942, p. 1417). These features are conspicuous in the basal 40-60 feet and may be restricted to the lower 140-170 feet.

The contact between the Sentinel Butte and Tongue River Members in the Dengate quadrangle is drawn at the base of the lowest bed of a sequence of thick dark bentonitic mudstone beds interbedded with light-colored siltstone and sandstone beds. The dark color of the basal mudstone contrasts sharply with the light-colored siltstone and sandstone beds typical of the uppermost part of the Tongue River. The contact is exposed at many localities in the southern part of the quadrangle but is especially well displayed on some steep-sided buttes in the western parts of secs. 1 and 12 and the eastern part of sec. 11, T. 138 N., R. 88 W., the northern part of sec. 16, T. 138 N., R. 87 W., the southeastern part of sec. 24, T. 139 N., R. 88 W., and the south half of secs. 16, 17, and 19, the north half of secs. 20 and 30, and the west half of secs. 23 and 26, T. 139 N., R. 87 W.

The outcrop appearance of the Sentinel Butte-Tongue River contact in the Dengate quadrangle is strikingly similar to its appearance in the Twin Buttes area north of the town of Sentinel Butte and in part of the South Unit Theodore Roosevelt National Park in western North Dakota. The contact in those areas was described by Royse (1967, p. 12 and 22, figs. 4 and 5A-C). In many other areas of western North Dakota the contact is drawn between a locally thick lignite, the HT Butte lignite bed of the Tongue River, and a silty sandstone which is commonly several tens of feet to more than 100 feet thick (Royse, 1967, p. 5-27).

The contact between the members was penetrated but could not be positively identified in the U.S. Geological Survey drill holes in sec. 18, T. 139 N., R. 87 W., and sec. 20, T. 138 N., R. 87 W., Dengate quadrangle, and in sec. 10, T. 139 N., R. 88 W., Glen Ullin quadrangle (Barclay, 1970, p. 13).

A badland, or "mud butte," topography, characterized by small round, nearly conical, and flat-topped bare buttes, is locally formed on the strata of the basal unit of the Sentinel Butte. Profiles of the buttes typically display reentrant slopes and benches at stratigraphic intervals that contain large amounts of swelling clays. In the Dengate quadrangle the dark mudstone at the base of the Sentinel Butte commonly forms a bench that has a thick hummocky clay crust above 20-30 feet of light-colored Tongue River sandstone and siltstone which stands in fluted near-vertical walls.

For purposes of discussion the Sentinel Butte Member can be divided into three parts, A, B, and C, of which only unit A is well exposed. Unit A, approximately 40-60 feet thick, is a sequence of interbedded light- and yellowish-gray sandstone and sandy siltstone, light-olive-gray and pale-olive clayey siltstone, dark-olive and greenish-gray bentonitic mudstone, and subordinate brownish-gray carbonaceous mudstone or claystone, grayish-brown carbonaceous shale, and lignite. Thin beds of white-weathering silicified carbonaceous shale are fairly common and form locally mappable marker beds. Large white-weathering silicified tree stumps, logs, and wood slabs occur in some lignite and carbonaceous shale beds. Limestone pods are scarce. A zone of locally thick and persistent lignite beds in the upper part of the unit is referred to as the Spring Valley-Richter lignite zone after the most prominent beds of the zone in the Glen Ullin and Dengate quadrangles.

Unit B, about 90-110 feet thick, is poorly exposed. In general, unit B appears to consist primarily of a sequence of light- and dark-colored beds similar to strata in unit A, a few thin lignite beds, and locally thick channel-filling sandstone beds.

Unit C is about 120-130 feet thick at Twin Buttes in the northwestern part of the Dengate quadrangle. At this locality unit C has a basal sequence of about 40 feet consisting of pale-yellow clayey siltstone, yellowish-gray to nearly white weathering coarse-grained siltstone and silty sandstone containing some thin interbeds of lignite and carbonaceous shale, and siltstone and thin lignite beds near the top. A thin to thick bed of brownish-black carbonaceous shale generally occurs at the base of unit C, and the top of this carbonaceous bed is locally mapped as the "white siltstone (-sandstone) marker" (ws) in reference to the dominant lithology of the overlying rocks. The light-colored siltstone unit at the base of unit C is an areally persistent lithologic unit that can be recognized on some high buttes to the west in the Glen Ullin quadrangle and farther westward (Barclay, 1970, p. 10). A lignite bed at the top of the light-colored siltstone sequence in the Twin Buttes area is believed to be equivalent to the beds that are burned at Rocky Ridge in the Glen Ullin quadrangle (Barclay, 1970, p. 10). On the northwest butte of Twin Buttes the lignite bed is overlain by 40 feet of olive-gray to dusky-yellow clayey siltstone and mudstone containing a limestone pod horizon and a thin carbonaceous shale at the top. Above the carbonaceous shale is 50 feet of yellowish-gray to pale-brown massive fine-grained sandstone that forms the cap rock of the buttes.

Quaternary deposits

The Quaternary deposits locally overlying beds of the Fort Union Formation with pronounced unconformity are glacial drift of Pleistocene age and alluvium of mostly Holocene age. Small unmapped landslide deposits are common on steep slopes, especially slopes formed on the basal clayey beds of the Sentinel Butte Member of the Fort Union.

Glacial drift

As shown in figure 1, the Dengate quadrangle is about 7 miles east of a segment of the outermost drift border of the Wisconsinan Stage as mapped by Colton, Lemke, and Lindvall (1963, fig. 1). Big Muddy Creek, which flows diagonally across the middle of the quadrangle, occupies part of the Muddy Creek trench, which was an ice-marginal diversion channel for glacial meltwater during the Pleistocene (Leonard, 1916; Benson, 1953, pl. 3). Wilson Creek, the principal tributary of Big Muddy Creek in the northern part of the quadrangle, lies along what was probably a meltwater channel tributary to the Muddy Creek trench (Benson, 1953, pl. 3).

Glacial drift in the quadrangle consists of free boulder erratics and sand and gravel deposits. Free boulder erratics, hereafter termed erratics, generally composed of granite, granodiorite, or gneiss, are scattered throughout the quadrangle but are most numerous south of Curlew Valley. The locations of erratics were noted on field sheets in order to ascertain the extent of drift in the quadrangle but are not shown on the map. Sand and gravel deposits occur on benches and buttes along the south side of Curlew Valley, the valleys of most of the major streams south of Curlew Valley, and the valley of Wilson Creek north of Curlew Valley. Hereafter in this report, "drift" will refer to sand and gravel deposits unless otherwise qualified.

Most of the drift in the area is in small, poorly exposed, and thin (1-5 ft thick) deposits. These deposits are chiefly composed of granule and pebble gravel and minor amounts of sand. A few of the deposits may contain boulder-size rocks; erratics are numerous on and near some deposits. The pebble fraction, which generally comprises about half of most deposits, is composed mostly of dark-reddish-brown subangular to subrounded platy and bladed fragments of ferruginous nodular layers and concretions derived from Fort Union strata. Well-rounded mudstone pellets, bladed subangular white-weathering silicified wood fragments, and subangular chips of ganister, all probably derived from the Fort Union, comprise a minor part of the pebble fraction. Generally less than 5 percent, and in some deposits less than 1 percent, of the pebble fraction is composed of well-rounded fragments of granite, granodiorite, amphibolite, various types of dark fine-grained gneiss, and well-indurated sedimentary rocks such as reddish-brown siltstone, black and light-olive-brown chert, and greenish-gray siltstone and sandstone.

Areas containing numerous scattered pebbles and cobbles of the kinds common to the drift occur in many parts of the quadrangle but are most abundant in the southeastern part. Most accumulations of these pebbles and cobbles are believed to be lag deposits of the coarser fractions of drift and were not mapped.

Most of the drift shown on the geologic map is believed to be outwash and inwash(?) deposits formed during a northeastern retreat of the ice front across a preglacial segment of the Muddy Creek trench and the present-day valley of Wilson Creek. Some of the very thin deposits may be till.

Alluvium

As mapped, alluvium consists of sand, silt, and clay principally derived from erosion of the Fort Union Formation and is mostly of Holocene age but may include some glacial deposits of Pleistocene age. The Holocene alluvium in Curlew Valley is at least 30-40 feet thick and that in Wilson Creek is probably 15-30 feet thick. Most of the alluvium mapped in the drainages tributary to Big Muddy Creek probably ranges in thickness from less than 5 to more than 25 feet. As mapped, the alluvium includes some colluvium on the sides of valleys.

The alluvium in Curlew Valley probably overlies thick glacial deposits of the former Muddy Creek trench. According to Henry Trapp of the U.S. Geological Survey (oral commun., Mar. 11, 1970), a hole drilled in the South Fork trench (a branch of the Muddy Creek trench) near Richardton, about 39 miles west, intersected about 280 feet of Quaternary fill.

STRUCTURE

The Dengate quadrangle is on the southeastern flank of the Williston basin. In the southwestern part of the quadrangle the Fort Union strata appear to be on the north or northeast flank of a structural high in, or just south of, the Glen Ullin quadrangle (Barclay, 1970, p. 35) and dip 20-40 feet per mile in a northeasterly direction. Northeast of Curlew Valley, the dip appears to flatten, and dip directions and amounts are highly variable. Local dips on some lignite beds that crop out along the sides of wide valleys appear much higher than 40 feet per mile and are probably the result of camber of the lignite beds into the valleys.

ECONOMIC GEOLOGY

Lignite

Lignite beds and zones

Lignite beds in the Fort Union Formation are shown on plate 1 and in a series of stratigraphic sections (pls. 2, 3). Lignite beds that could be mapped over wide areas of the quadrangle were given informal names. The names and corresponding letter designations of beds are given in the generalized stratigraphic section of the Fort Union rocks exposed in the quadrangle (pl. 2).

In general, all beds 1 or more feet thick were mapped. The thickest outcropping beds are 7-9 feet thick in some places. Where two or more beds were found to be so close together that it was not possible to clearly separate their traces on the geologic map, only the trace of the more persistent bed is shown.

Except for the local bed inferred in the N½ sec. 15 and the south edge of the SE¼ sec. 10, T. 138 N., R. 87 W., no mappable lignite beds were found in outcrops below the ys marker in the quadrangle. Lignite in single beds 2.5-4 feet thick was encountered below the ys marker in the drill holes in sec. 20, T. 138 N., R. 87 W., and sec. 18, T. 139 N., R. 87 W. (pls. 2, 3).

Lignite beds occur in many parts of the 445- to 495-foot interval of the Fort Union Formation exposed in the Dengate quadrangle. Individual lignite beds are lenticular, but lignite zones tend to be areally persistent. The thickest and most persistent lignite beds in the area are the Tavis Creek bed in the upper part of the Tongue River Member and some of the beds of the Spring Valley-Richter lignite zone in the Sentinel Butte Member.

The Tavis Creek lignite bed is commonly 20-40 feet below the top of the Tongue River Member in the Dengate quadrangle. The thickest outcrops of this bed generally occur west of Curlew Valley where thicknesses of 5-6 feet in a single bed were measured in secs. 1 and 23, T. 138 N., R. 88 W. Locally, instead of a single bed, two beds 1-20 feet apart crop out near the normal stratigraphic position of the Tavis Creek bed. Where the separation between the two beds is less than 10 feet, only the lower bed is mapped; it is designated the Tavis Creek bed. Where the separation is more than 10 feet, the lower bed, which invariably appears to be the thicker of the two, is mapped as the Tavis Creek bed and the upper bed is mapped as a local upper bench of the Tavis Creek bed. This local bench, which is a carbonaceous shale or thin lignite bed in some places, appears to merge with the main Tavis Creek bed in some areas of the quadrangle. The Tavis Creek bed is approximately equivalent to Stephens' (1970a, b) Beaver Creek bed and to Hancock's (1921, p. 13) C bed, and at Klondike Butte in the New Salem quadrangle it correlates well with the bed H. L. Smith (unpub. map, U.S. Geological Survey) designated as the Cut Bank Creek bed.

The Spring Valley-Richter lignite zone is in the lower part of the Sentinel Butte Member. Beds of the zone were mapped in the Glen Ullin (Barclay, 1970, p. 15-16) and Dengate quadrangles, and the zone was recognized in parts of the Heart Butte, North Almont, and New Salem quadrangles. The Spring Valley and Richter beds mapped in the Heart Butte area by Stephens (1970a, b) are in the Spring Valley-Richter zone, although they may not be exactly equivalent to beds of the same names in the Glen Ullin and Dengate quadrangles. The thickest beds of the Spring Valley-Richter zone in the Glen Ullin and Dengate quadrangles are the Spring Valley and Richter beds after which the zone is named. The Spring Valley bed was mined at the Spring Valley mine in sec. 22, T. 138 N., R. 88 W., Glen Ullin quadrangle. The Spring Valley bed was mapped extensively in the Glen Ullin quadrangle but at only a few places near the west edge of the Dengate quadrangle. The Richter bed was mined at the Richter mine in sec. 13, T. 139 N., R. 88 W., in the northwestern part of the Dengate quadrangle where it is commonly 7-9 feet thick. The Richter bed, or clinker from its in situ combustion, occurs in most areas of the quadrangle except the southeast corner.

The Spring Valley and Richter beds are at least partly equivalent and are approximately correlative with Hancock's (1921, p. 13) D bed (Barclay, 1970, p. 16). In many parts of the Dengate quadrangle, the Spring Valley-Richter zone does not contain a single thick bed but has one to three lignite beds, 1-4 feet thick, none of which could be traced very far. In those areas where a single Richter or Spring Valley bed could not be identified, a thin bed of silicified carbonaceous shale or, less commonly, of carbonaceous shale or lignite, which generally crops out near the base of the Richter bed and which in some areas is approximately equivalent to the Richter bed, was mapped as a marker (srl) for the approximate position of the base of the Spring Valley-Richter zone. A similar bed (sru) near the top of the Spring Valley-Richter zone was also locally mapped. In both cases the bed so mapped may not be the same bed everywhere.

In addition to the Tavis Creek, the Spring Valley, and the Richter beds and the local beds associated with them, several lignite beds, most of which could be traced for only short distances, were mapped. Among these are a local bed generally about 20-30 feet below the Tavis Creek bed, local beds between the Spring Valley-Richter zone and the white siltstone marker (ws), and local beds 5-35 feet above the white siltstone marker. The local beds above the white siltstone marker, which occur only on a few of the highest buttes of the area, and the local bed below the Tavis Creek bed appear to belong to persistent intervals of lignite beds that can be recognized in the Glen Ullin quadrangle to the west (Barclay, 1970, p. 16-17).

Physical and chemical characteristics

The lignite in the Fort Union Formation in the Dengate quadrangle is commonly blackish brown, hard, and woody and is slabby when freshly dug. It characteristically slacks rapidly when exposed to the atmosphere.

Core samples of several lignite beds and of some shale, claystone, and siltstone beds associated with a few of the lignite beds were obtained from holes drilled in the quadrangle during a U.S. Geological Survey drilling program in 1966 (Smith, 1970, p. 23-24, 29-33). Analyses of the core samples by the U.S. Bureau of Mines and the U.S. Geological Survey are presented in table 2.

Outcrop samples of lignite and various kinds of rocks containing carbonaceous material or plant impressions were collected from the Glen Ullin and Dengate quadrangles during the summer of 1966 by the author and J. D. Vine, U.S. Geological Survey. Results of the spectrographic analyses of the lignite samples collected in the Glen Ullin quadrangle by Vine were reported by Barclay (1970, table 2). Most of the results of spectrographic analyses and the results of total carbon analyses of the rest of the Glen Ullin samples and of all the Dengate samples collected by Vine are given in table 3 with Vine's permission. The results of spectrographic and uranium (eU) analyses of the samples collected by the author in the Dengate and Glen Ullin quadrangles are given in table 4. Omitted from the tables were the results for silicon, sodium, potassium, phosphorus, and most of those minor elements not found in any of the samples. In addition to eU analyses, the U in sample DC-1 and the U in sample GU-49 were determined fluorometrically by E. J. Fennelly of the U.S. Geological Survey and determined to be < 10 and 10 ppm, respectively.

Spectrographic and eU analyses of rocks containing small amounts of carbonaceous material and of a few of their silicified counterparts were done primarily to furnish data on the elemental content of a class of rocks that is common in the Fort Union Formation and that has been of some interest in uranium exploration. The low abundance of chemical elements other than calcium in the silicified carbonaceous rocks compared to that in their unsilicified counterparts indicates that the silicified rocks were leached prior to silicification. The leaching agent might have been the same high ph solutions that probably introduced and redistributed silica in the rock for later silicification. The silicified rocks may represent the leached tops of fossil soil horizons. Silicification of at least some of the carbonaceous shales may have taken place during early diagenesis. In thin section a sample of silicified carbonaceous shale was found to contain a large amount of plant fiber replaced by quartz and chalcedonic quartz.

Ash of lignite from the Fort Union Formation is primarily composed of a mixture of sulfates, oxides, and silicates of calcium, silica, aluminum, iron, magnesium, and sodium with much lesser amounts of potassium and a number of minor elements of which the most abundant are commonly titanium, phosphorus, barium, strontium, boron, copper, and manganese (Sondreal and others, 1968, p. 6-7, 23-24, tables 3, 12). The compositions of the ash of 18 lignite core samples (table 2c) and of three lignite outcrop samples (tables 3, 4) from the Dengate quadrangle are given in terms of selected major and minor elements as determined by semiquantitative spectrographic analysis. Omitted were potassium, sodium, silicon, and most of those minor elements not detected in any of the samples. Phosphorus, which has a detection limit of about 0.2 percent in the analytical method used, was looked for but not detected in the lignite samples listed in tables 2 and 4 and was omitted from the tables.

The compositions of the minor elements in the ash of both the lignite core samples and the outcrop samples are similar to compositions reported for Fort Union lignite ash of North Dakota and the east edge of Montana (Zubovic and others, 1961, tables 3, 4; Sondreal and others, 1968, tables 3, 12).

The percentage of sodium in ash has been cited by U.S. Bureau of Mines researchers at Grand Forks, N. Dak., as a useful index of the fouling potential of Fort Union lignite used in many of the large power generating facilities of the Northern Great Plains-Great Lakes region (Gronhovd, 1968, p. 4-5). According to Gronhovd, Harak, and Paulson (1968, p. 77-80), fouling of convection surfaces and the rate of formation of slag deposits on boiler walls are excessive for lignite with 9 percent Na_2O in ash. Table 2b shows amounts of magnesium, calcium, sodium, and potassium oxides in lignite core samples and, for comparison purposes, in carbonaceous rocks adjacent to a few of the lignite beds. Using the percentage of ash given in table 2c, the calculated percentage of sodium oxide in lignite ash ranges from 2.4 percent in DC-1-1b to 16.5 percent in D-2-0 and is more than 9 percent in DC-1-3 through 5 and in DC-2-0 and DC-2-3. The sodium content of each of these samples may not be representative of the beds sampled; Gronhovd, Harak, and Paulson (1968, p. 77) reported that sodium content varies markedly from place to place in a single mine.

A portion of each of the lignite core samples used in the chemical analyses was studied by X-ray diffractometer. Both raw lignite and ash produced by low-temperature oxidation of the lignite were used in the study. The low-temperature ash samples were prepared by I. C. Frost of the U.S. Geological Survey after the method of Gluskoter (1965). Quartz, pyrite, calcite, siderite(?), and clay minerals were the minerals detected. Feldspar occurs in very small amounts in some samples, and heulandite-clinoptilolite(?) was found in sample DC-1-1b in which it is the most abundant mineral present. No mineral containing sufficient sodium to account for the amounts that were detected in the ash could be found in any sample except DC-1-1b. Researchers at the U.S. Bureau of Mines, Grand Forks, N. Dak., who have done considerable work on the composition of

Fort Union lignites have not found any sodium-rich minerals in the North Dakota lignite (Spencer, 1969, p. 50) and suggest that the sodium is "probably attached to the coal molecule" (Gronhovd, 1968, p. 5).

In view of the current interest in determining and evaluating possible sources of mercury contamination of the environment, lignite core samples from U.S. Geological Survey drill holes in both the Glen Ullin (Barclay, 1970) and Dengate quadrangles were analyzed. The results of the analyses appear in table 5.

Development

Some lignite beds in the Dengate quadrangle have been mined in the past principally for local use. Mine workings were generally small shallow open pits. The mine on the Tavis Creek bed near the middle of the west edge of sec. 9, T. 138 N., R. 87 W., might have had some underground workings. The largest mine in the area was the Richter mine in the NE¼ sec. 13, T. 139 N., R. 88 W.; its last production figures, for the period July 1, 1962, to June 30, 1964, were 6,014 tons, value $15,425 (N. Dak. Coal Mine Inspector, 1964, p. 11). None of the mines in the quadrangle were active during the fieldwork for this report.

Construction materials

Gravel

Gravel in the quadrangle occurs in glacial drift, but most of the drift is not thick enough or extensive enough to be economically valuable as a source of gravel. Some drift gravels, used locally to surface roads, have been quarried just beyond the mapped area at the southern end of the deposits in the SW¼ sec. 22 and the SE¼ sec. 7, T. 138 N., R. 87 W.

Clinker

Clinker is the baked and fused rock produced by the in situ combustion of coal. The cause of in situ burning of lignite in North Dakota is primarily spontaneous combustion (Blain, 1955, p. 139). Burning in the Dengate quadrangle probably occurred during both Holocene and Pleistocene time (Barclay, 1970, p. 21). Clinker deposits are extensive and thick in some areas in the northern part of the quadrangle where most of the deposits are associated with the Richter lignite bed. Clinker is used extensively to surface roads.

TABLE 5.--Mercury in drill core samples of lignite in the Fort Union Formation, Dengate and Glen Ullin quadrangles, Morton County, N. Dak.

[Analyses by P. R. Norton and Claude Huffman, Jr., U.S. Geological Survey, using the stannous chloride flameless atomic-absorption method employing a H_2SO_4-$KMnO_4$ digestion]

Field No.	Location of drill hole	Sample interval depth (ft)	Sample description	Fort Union Formation Member	USGS Lab. No.	Hg (ppm)
DC-1-1a	NE. cor. SE¼SE¼NE¼ sec. 20, T. 138 N., R. 87 W.	39.8-41.5 (upper part)	Richter lignite bed (srl bed?).	Sentinel Butte.	D137652	0.08
DC-1-1b	do.	39.8-41.5 (lower part)	---do.	---do.	D137653	.18
DC-1-2a	do.	87.5-92.8	Tavis Creek lignite bed.	Tongue River.	D137655	.16
DC-2-0	SE. cor. SE¼SW¼SW¼ sec. 18, T. 139 N., R. 87 W.	54.5-56.3	Lignite; local bed.	Sentinel Butte.	D137659	.05
DC-2-3	do.	166.1-168.5	Tavis Creek lignite bed.	Tongue River.	D137665	.16
DC-2-4	do.	237.6-238.9	Lignite.	---do.	D137666	.12
DC-2-7	do.	281.5-283.2	Lignite, impure.	---do.	D137669	.26
GUC-1-1	NE¼NE¼SE¼ sec. 20, T. 138 N., R. 88 W.	120.0-129.9 (partings removed; actual thickness 9.0 ft)	Spring Valley lignite bed.	Sentinel Butte.	D137670	.43
GUC-2-1	SE¼NE¼ sec. 32, T. 139 N., R. 88 W.	162.6-166.4	Unnamed.	Tongue River.	D137671	.10
GUC-3-1	SW¼SE¼NW¼ sec. 10, T. 139 N., R. 88 W.	65.2-67.3	Haymarsh Creek lignite bed.	Sentinel Butte.	D137672	.14
GUC-3-2	SW¼SE¼NW¼ sec. 10, T. 139 N., R. 88 W.	85.0-89.6	Tavis Creek(?) lignite bed.	Tongue	D137673	.08

Ganister blocks

Areas containing concentrations of scattered ganister blocks are shown on plate 5, an overlay to be used with the geologic map.

Ganister blocks are angular cobble- and boulder-sized blocks and slabs of hard dense silicified siltstone or mudstone that are scattered over the prairie in many parts of the quadrangle. The blocks are generally buff to brownish gray, have a polished appearance on some weathered surfaces, and characteristically contain tubular plant molds. Some of the blocks may be glacial erratics or lag deposits of glacial drift. Some of the drift contains angular cobble- and pebble-sized fragments of ganister, and in some areas scattered pebbles and boulders of igneous and metamorphic rocks occur with concentrations of ganister blocks. The ganister blocks in the quadrangle were probably originally derived from beds in the Fort Union Formation (Denson and Pipiringos, 1969, p. 15; Barclay, 1970, p. 22).

In North Dakota ganister blocks have been widely used for riprapping earthfill dams, water diversion channels, and river banks.

Oil and gas

No test wells for oil and gas have been drilled in the Dengate quadrangle. The closest producing well is about 28 miles west in sec. 15, T. 137 N., R. 92 W., Stark County, where Texaco has recovered oil from the Upper Ordovician Red River Formation at a depth of more than 10,000 feet (N. Dak. Geological Survey, 1969, p. 24). Rocks at depth in the quadrangle are valuable prospectively for oil and gas. The sedimentary section underlying the area is probably more than 10,000 feet thick (Hansen, 1957). It includes formations of Ordovician through Permian age (Anderson and Mendoza, 1960), some of which have produced oil in other parts of the Williston basin in North Dakota (N. Dak. Geological Survey, 1969).

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