Preliminary geologic map of the Glen Ullin quadrangle, Morton County, North Dakota.

by

C. S. Venable Barclay

U. S. Geological Survey.
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October 16, 1970

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Preliminary geologic map of the Glen Ullin quadrangle, Morton County, North Dakota, by C. S. Venable Barclay. Geologic map, text, two sheets of stratigraphic sections, and map showing distribution of ganister blocks.

A copy of the map is enclosed.

Joyce Boshart

Joyce V. Boshart

Enclosure

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UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey
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For release October 19, 1970

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Preliminary geologic map of the Glen Ullin quadrangle, Morton County, North Dakota, by C. S. Venable Barclay. Geologic map (scale 1:24,000), text, two sheets of stratigraphic sections, and map showing distribution of ganister blocks.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary geologic map of the Glen Ullin quadrangle, Morton County, North Dakota

By

C. S. Venable Barclay

Open-file map
1970

INTRODUCTION

The Glen Ullin quadrangle occupies approximately 51 square miles in western Morton County, southwestern North Dakota. Glen Ullin, a small agricultural community on the Northern Pacific Railroad, about 52 miles west of Bismarck, is near the center of the quadrangle (fig. 1).

The Glen Ullin 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quadrangles (fig. 1) that are being mapped by the U.S. Geological Survey to furnish a basis for classification of lands withdrawn by the Federal Government pending classification for coal and to contribute to the geologic map atlas of the United States.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 Glen Ullin quadrangle was done during the late summers and early falls of 1964 and 1965.

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and nearby quadrangles (Smith, 1970) to gather information on the existence, thickness, and depth of lignite beds in withdrawn Federal lands.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

PHYSIOGRAPHY

The Glen Ullin quadrangle is in the Missouri Plateau section of the Great Plains physiographic province (Fenneman, 1931, p. 61). The northern part of the area is characterized by rolling prairies, scattered sandstone hills and buttes, and broad valleys containing small streams; the southern part is characterized by steep-sided buttes and broad tablelands in which lignite beds of the Fort Union Formation have burned and the overlying rocks have been baked to form a resistant rimrock. Locally, dissection of clayey parts of the Fort Union Formation has produced badland topography.

The principal streams are Big Muddy Creek and Haymarsh Creek, both underfit streams which flow eastward and southeastward across the central and northern parts of the quadrangle, respectively. Beyond the quadrangle, Big Muddy Creek flows southeastward to merge with the Heart River, a tributary of the Missouri River.

The climate of the area is fairly typical of continental interiors of the temperate zone: the annual rainfall is less than 20 inches, minimum temperatures of the long severe winters are near -30°F, and maximum temperatures of the short hot summers are near 100°F.

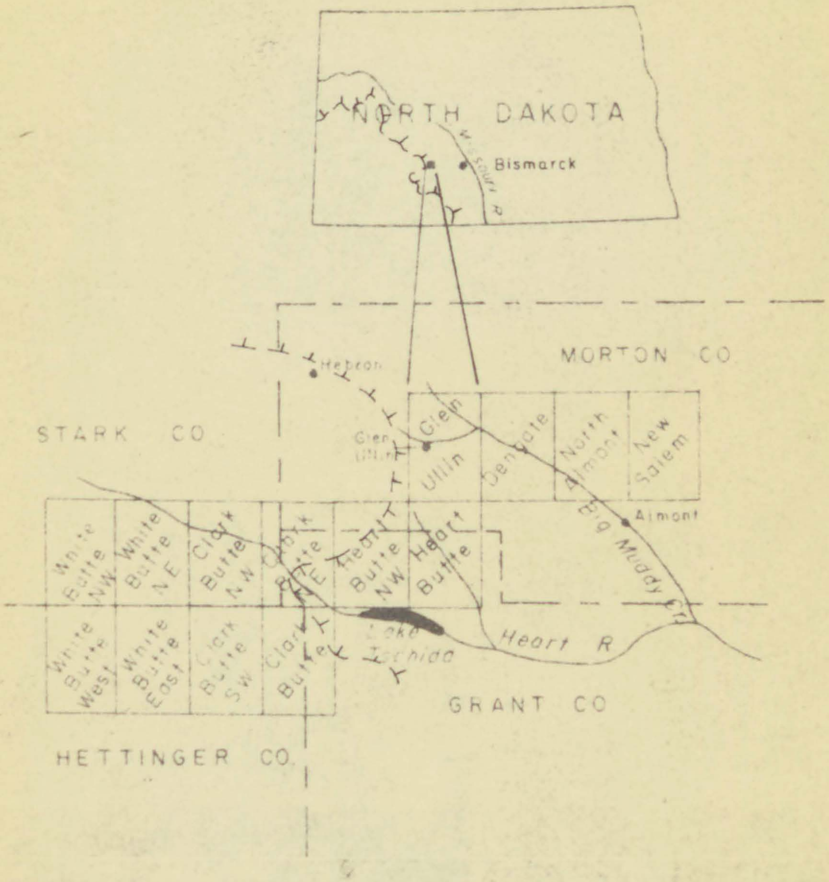

FIGURE 1.--Index map showing the location of the Glen Ullin and other 7½-minute quadrangles in North Dakota being mapped by the U.S. Geological Survey. Hachured lines show the outermost drift border of the Wisconsin Glaciation as mapped by Colton, Lemke, and Lindvall (1963).

Much of the area is under cultivation for grain, mostly wheat; the rest generally has a cover of prairie grass. Buffalo berry bushes are common on some slopes, mats of low juniper shrubs grow on some clinker-capped buttes and benches, and deciduous trees grow along watercourses.

Bedrock exposures in the quadrangle are generally few and scattered; the best exposures are in the southern part in areas of badland topography.

STRATIGRAPHY

Only Tertiary rocks and Quaternary deposits are exposed in the quadrangle. The Tongue River and Sentinel Butte Members of the Fort Union Formation of Paleocene age underlie most of the surface. The Fort Union is locally covered by Pleistocene glacial drift or Quaternary alluvium. A generalized stratigraphic section of the Fort Union rocks exposed in the quadrangle is presented on plate 2. Stratigraphic sections measured in the Fort Union 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), but in the Glen Ullin quadrangle only the Tongue River and Sentinel Butte Members were recognized. 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 compose an upper continental sequence that is exposed over most of western North Dakota (Carlson, 1969). Locally, in southwestern North Dakota the Sentinel Butte Member is conformably (Hickey, 1969) overlain by the Golden Valley Formation (Eocene) or unconformably by the White River Formation (Oligocene).

About 265-305 feet of the Fort Union is exposed in the Glen Ullin quadrangle. The base of the formation is not exposed, and it was not reached in the holes drilled for the U.S. Geological Survey in 1966. The upper part of the formation was removed by erosion. The closest exposures of the base of the Fort Union, the contact between the Cannonball or Ludlow

Member and the Hell Creek Formation, are about 35 miles southeast of Glen Ullin in southeastern Morton County (Laird and Mitchell, 1942, pl. I; Carlson, 1969). The nearest exposure of the top of the formation is near Hebron, N. Dak., 12 miles west of Glen Ullin, where the contact between the Eocene Golden Valley Formation and the Sentinel Butte Member is well exposed on a few high buttes a few miles west and north of the town (Benson, 1953, p. 71, 82-83).

That part of the Fort Union Formation exposed in the Glen Ullin 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 bodies which appear to fill broad channels in the underlying rocks. Rocks in the formation are generally light shades of gray, yellow, and olive and darker shades of gray, olive gray, and greenish gray. Sandstone is generally light colored, very fine grained, and locally silty. Sandstone in thick lenticular channel-filling deposits is commonly fine grained and locally conglomeratic. Clasts in conglomeratic parts are generally rounded pebbles of claystone or siltstone and angular fragments of ferruginous nodules. Siltstone is generally clayey and is light or moderately dark, depending on the clay content. Claystone is commonly dark and silty. Silty claystone and clayey siltstone are the most abundant rock types in the formation. The term "mudstone" is used in this report 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 is light brownish gray, weathers yellowish orange, and occurs in discoidal pods generally 1-2 feet thick, 3-6 feet in diameter.

Thin (generally about 1 in. thick) locally resistant ferruginous layers form dark-yellowish-orange bands in some exposures of Fort Union rocks. These layers are most abundant in siltstone to claystone sequences where they commonly occur in claystone near the interface between claystone and siltstone laminae. Less commonly, they are also in clayey laminae in sandstone beds. Many intervals of core recovered from U.S. Geological Survey drill holes in the quadrangle contain very thin beds and laminae of hard yellow very limy claystone which commonly enclose a thin limestone core.

In some of these, the limestone core is pyritic. The thin limy layers have lithologic associations similar to those of the thin ferruginous beds at the surface and are believed to be the unweathered counterparts of those beds.

Fossil animal and plant material is locally abundant but generally fragmental. Snail and clam shells were seen in some mudstone beds. Carbonized rootlets and wood fragments are common in carbonaceous rocks. Some fine-grained rocks contain impressions of leaves and stems, and some beds of sandy mudstone and siltstone contain tubular stem molds. White-weathering petrified stumps and wood fragments are locally abundant in some carbonaceous shale or lignite beds.

Carbonate is the predominant cementing material in most of the rocks of the Fort Union. Insoluble-residue determinations of 138 samples (42 from the Tongue River, 96 from the Sentinel Butte) representative of the clastic rocks exposed in the quadrangle were made by R. F. Gantnier, U.S. Geological Survey, using approximately 3N HCL. The results of these determinations show that acid-soluble material, all but insignificant amounts of which is assumed to be carbonate, ranges from 3 to 31 percent by weight in 96 percent of the samples and from 38 to 59 percent in 4 percent of the samples.

Most of the rocks are not well indurated; they 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.

Iron sulfide in small (1-in. diameter) round balls, in larger nodules, and in irregular branching shapes was found in drill core samples and on outcrops in most rock types but appears to be most abundant in or adjacent to lignite beds. Limonitic, jarositic, and commonly gypsiferous nodules and irregular masses--the oxidized and hydrolyzed remnants of iron sulfide bodies--are locally abundant, especially in sandstone, carbonaceous shale, and lignite. Individual crystals and very thin lenticles of fibrous gypsum are also locally found in carbonaceous beds.

Tongue River Member

Only 60-75 feet of the uppermost part of the Tongue River is exposed in the quadrangle. Another 160 feet of the Tongue River was encountered in the drill hole in sec. 32, T. 139 N., R. 88 W. According to Tisdale (1941, p. 10), a sandstone about 100 feet thick occurs at the base of the Tongue River in the Heart River area about 15-20 miles south of Glen Ullin. Using Tisdale's thicknesses and the mapping by Stephens (1970a, b), the original thickness of the Tongue River prior to erosion in the Glen Ullin quadrangle is estimated to be about 260-320 feet.

In the area between the southern part of the Dengate quadrangle and the Heart River and between the town of Almont and Lake Tschida, the Tongue River can locally be divided into two parts. The lower part, about 100-200 feet thick, consists of thick light- or yellowish-gray lenticular sandstone beds, thick olive and brownish-gray mudstone and subordinate claystone beds, and a few carbonaceous shale and lignite beds. The somber color of the fine-grained rocks is the most characteristic feature of the lower part of the Tongue River. The rocks in the lower 75 feet of the drill hole in sec. 32, T. 139 N., R. 88 W. (pl. 3), may belong to the lower part of the Tongue River. Clayey siltstone and other fine-grained rocks in this interval in the drill hole range from light olive to dark olive to greenish gray, whereas similar rocks above this interval are generally light gray or light olive gray. Seventeen feet of sandstone at the bottom of the hole may be partly correlative to the basal sandstone of the Tongue River described by Tisdale (1941, p. 10-12).

The upper part of the Tongue River Member ranges in thickness from about 100 to 160 feet and consists of mudstone, clayey siltstone, siltstone, and sandstone, a few lignite beds, and at least two limestone pod horizons. Sandstone beds are generally yellowish gray or light olive gray. Finer grained rocks are mostly pale olive, olive gray, or dusky yellow. In general, this part of the Tongue River weathers light yellowish orange. Commonly, the upper part of the Tongue River is marked at the base by a 20- to 30-foot sequence of pale-yellow-weathering clayey siltstone and subordinate sandstone beds. A limestone pod horizon generally occurs near the top of the pale-yellow sequence.

The Tavis Creek lignite bed, which ranges in thickness from less than 5 to more than 11 feet (stratigraphic section 17, pl. 2), generally occurs 20-40 feet below the top of the Tongue River and is useful as a stratigraphic marker. It was traced as far east as Klondike Butte in the southwestern part of the New Salem quadrangle where it is about 25 feet below the top of the Tongue River Member. The Tavis Creek bed is approximately equivalent to Stephens' (1970a, b) Beaver Creek bed, which is estimated to be 35-40 feet below the top of the Tongue River along Beaver Creek near the west edge of the Heart Butte NW quadrangle. A local lignite bed, commonly 1-2 feet thick and generally 15-20 feet below the Tavis Creek bed, is near the base of the Tongue River section exposed in the Glen Ullin quadrangle (strat. secs. 3 and 29, pl. 2, and 34, pl. 3).

That part of the Tongue River Member above the Tavis Creek bed is locally well exposed in the Glen Ullin area and consists predominantly of dusky-yellow clayey siltstone and yellowish-gray lenticular sandstone. A horizon of limestone pods generally crops out near the top. Olive-gray to pale-olive silty claystone occurs at the base; similar rocks at the top are capped by a thin carbonaceous layer. In the Glen Ullin quadrangle this carbonaceous layer is commonly less than 1 inch of lignitic carbonaceous shale. In the Dengate and Almont quadrangles to the east, a lignite bed at this horizon is commonly more than 6 inches thick, locally contains white-weathering silicified wood slabs and large tree stumps, and may be approximately equivalent to the HT Butte lignite, a stratigraphic marker for the top of the Tongue River in western North Dakota (Royse, 1967, p. 5).

Samples of claystone and mudstone adjacent to mapped lignite beds in the upper part of the Tongue River were collected for palynological age assignment. Three samples collected in sec. 24, T. 138 N., R. 89 W., near the base of the Tavis Creek bed (USGS Paleobot. locs. D3815-A and B) and near the base of a local bed 15-20 feet below (D3816) (strat. sec. 3, pl. 2), yielded Paleocene assemblages (R. H. Tschudy, written commun., Aug. 16, 1966). Three samples collected in sec. 32, T. 139 N., R. 88 W., near the top of the Tavis Creek bed (D3994-D) and near the top (D3994-A) and the base (D3994-B) of a local bed approximately 20 feet below the base of the Tavis Creek bed (strat. sec. 34, pl. 3), contained middle to upper Paleocene assemblages (E. B. Leopold, written commun., Nov. 4, 1967, Feb. 24, 1970).

Sentinel Butte Member

The Sentinel Butte Member, about 200-240 feet thick, is lithologically similar to the Tongue River Member. The principal features that characterize the Sentinel Butte in western North Dakota have been ably discussed by Royse (1967, 1970). In the Glen Ullin area the Sentinel Butte Member is characterized by drab bentonitic mudstone and siltstone, locally abundant white-weathering silicified carbonaceous shale, stumps, and logs, and the "mud butte" topography described by Seager and others (1942, p. 1417). The drab beds are commonly interbedded with light sandstone and siltstone, and the mud buttes formed on the rocks of the Sentinel Butte Member generally have a light and dark banded appearance. All these features are conspicuous in the basal 50-70 feet and may be restricted to the lower part (120 ft) of the Sentinel Butte.

The contact between the Sentinel Butte and Tongue River Members is drawn at the base of the lowest bed of a sequence of thick dark bentonitic mudstone beds interbedded with light siltstone and sandstone beds. The dark color of the basal mudstone contrasts sharply with the light 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 it is especially well displayed in areas of mud-butte topography in the Tavis Creek drainage.

The outcrop appearance of the Sentinel Butte-Tongue River contact in the quadrangle is similar to its appearance in western North Dakota in the Twin Buttes area north of the town of Sentinel Butte and in part of the South Unit of Theodore Roosevelt National Park. The contact in those areas has been described by Royse (1967, p. 12 and 22, fig. 4D). 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 an overlying silty sandstone that in some places is 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 identified positively in the U.S. Geological Survey drill hole in sec. 10, T. 139 N., R. 88 W. In the columnar section of the drill hole (pl. 3) the contact is shown at the base of a silty and clayey sandstone in which much of the silt and clay occurs as lumps, irregular lenticles, and chaotically deformed laminae of silty claystone. The contact could be at the top of the

2.1-foot lignite bed shown approximately 10 feet higher in the drill hole. If this is the contact, the lignite locally mapped as the Haymarsh Creek lignite is equivalent to the HT Butte lignite of western North Dakota.

The Sentinel Butte Member in the Glen Ullin quadrangle can be divided into three parts, designated A, B, and C. Only unit A is well exposed; units B and C are poorly exposed in a few scattered outcrops.

Unit A, the basal unit, is approximately 50-70 feet thick. It is best exposed in the southern part of the quadrangle where it consists of thickly interbedded light- and yellowish-gray lenticular sandstone and sandy siltstone, light-olive-gray and pale-olive clayey siltstone, and dark-olive and greenish-gray bentonitic mudstone and subordinate brownish-gray carbonaceous claystone or mudstone, 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 also occur along some lignitic horizons. Limestone pods are scarce. Fragments of pelecypods (Unio?) occur locally in mudstone beds near the base of unit A. A zone of locally thick and persistent lignite beds occurs in the upper part of the unit. This zone is here referred to as the Spring Valley-Richter lignite zone for the most prominent beds of the zone in the Glen Ullin and Dengate quadrangles. Beds of this zone were traced to the west for 1-2 miles beyond the quadrangle boundary and to the south into the Heart Butte quadrangle and were recognized as far east as the New Salem quadrangle. Stratigraphic sections measured beyond the quadrangle boundaries in secs. 3 and 10, T. 138 N., R. 89 W., and sec. 11, T. 138 N., R. 88 W., are included on plate 3.

A badland, or "mud butte," topography, characterized by small round, conical, and flat-topped bare buttes, has locally formed on the strata of unit A of the Sentinel Butte. Profiles of the buttes typically display reentrant slopes and benches at stratigraphic intervals that contain large amounts of swelling clays. The dark mudstone at the base of the Sentinel Butte commonly forms a bench which has a thick hummocky clay crust above 20-40 feet of light-yellow Tongue River sandstone and siltstone that stands in fluted near-vertical walls.

Unit B, the middle unit of the Sentinel Butte, is best exposed in the southern part of the quadrangle where it is about 95-115 feet thick and commonly has 20-40 feet of light-yellowish-gray locally silty or clayey sandstone near the base. Above this sandstone in the Rocky Ridge area is a sequence of light and dark beds similar to the sequence near the base of the Sentinel Butte. In the northern part of the quadrangle, unit B is about 50-85 feet thick.

Unit C, the upper unit of the Sentinel Butte, is about 50-80 feet thick. In the southern part of the quadrangle it typically has a basal sequence of 20-30 feet of yellowish-gray-weathering to nearly white weathering coarse-grained siltstone and some thin beds of lignite and carbonaceous shale and siltstone. A bed of brownish-black carbonaceous shale, 2-5 feet thick, generally occurs at the base. The top of this basal carbonaceous bed--or the base of the white siltstone sequence where the carbonaceous bed was not found--is locally mapped as the "white siltstone marker" (ws on pls. 1, 2, and 3). The white siltstone sequence is well exposed on Rocky Ridge and Spring Butte in the southern part of the quadrangle, on a high butte in sec. 10, T. 138 N., R. 89 W., west of the Glen Ullin area (pl. 2), and near the base of Twin Buttes in the Dengate quadrangle. In the last two named localities the white siltstone interval is locally thinner than it is in the Rocky Ridge area and is separated from the basal carbonaceous shale or lignite bed by pale-yellow clayey siltstone. In the Rocky Ridge-Spring Butte area the white siltstone sequence is overlain by 15-20 feet of olive-gray siltstone and mudstone that contains a thin lignite bed at the base and a thick lignite bed at the top. Red clinker from the burning of the highest bed or beds caps Rocky Ridge, Spring Butte, and the butte of the triangulation station in the SE¼NW¼ sec. 21, T. 138 N., R. 88 W. In the northern part of the quadrangle a carbonaceous shale or lignite bed believed to be correlative with the carbonaceous shale at the base of the white siltstone sequence consistently crops out at an altitude of about 2,200 feet. Locally it is overlain by channel-filling sandstone (strat. sec. 57, pl. 3) or by clayey siltstone and finer grained rocks overlain by other lignite beds and fine-grained rocks, all capped by sandstone.

Quaternary deposits

Quaternary deposits that unconformably overlie the Fort Union Formation are glacial drift of Pleistocene age and alluvium of Pleistocene and 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 Glen Ullin quadrangle is just 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 and Haymarsh Creeks, which cross the northern part of the quadrangle, occupy part of the South Fork trench and part of the Elm Creek trench, respectively, which were ice-marginal diversion channels for glacial meltwater during the Pleistocene (Leonard, 1916; Benson, 1953, pl. 3). Below the confluence of Haymarsh and Big Muddy Creeks, the South Fork trench is known as 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 numerous on high ground near the south border of the quadrangle and near the principal unnamed watercourse of the northwestern part. 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 geologic map. The sand and gravel deposits are most numerous on some high benches in the southeastern part of the quadrangle near the drainage divide between Big Muddy and Heart Butte Creeks, on small buttes and in low elongate mounds in the valleys and tributary valleys of Spring Valley and Tavis Creek, and on benches and in low ridges in the northwestern part of the quadrangle. 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 rocks as large as boulders. Erratics are numerous on and near some deposits. The pebble fraction, which comprises approximately half of most deposits, is composed primarily 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 silicified siltstone, 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.

Some of the deposits that cap low ridges in the northwestern part of the quadrangle are thicker and sandier than those in the southern part. One of these elongate deposits is exposed in the SE¼ sec. 14, T. 139 N., R. 89 W. (pl. 1). Near its center it consists of (1) 15-20 feet of yellowish-gray well-stratified sand, conglomeratic sand, and thin gravel beds overlain by (2) brown gravel less than 5-15 feet thick that is similar in composition to the thin drift exposed elsewhere in the quadrangle. The base of the deposit is not exposed, but it appears to rest on an erosion surface on Fort Union rocks. In unit (1) gravel and conglomeratic sand increase in abundance toward the base. Igneous and metamorphic rock fragments are rare in unit (1) and abundant in unit (2). The sand near the base of unit (1) contains a few laminae composed of very small flakes of "clinker." Cut-and-fill structures are common in sand near the top of unit (1). The contact between the two units of the drift deposit is erosional, and the gravels of unit (2) fill shallow channels in the top of unit (1).

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 southern and northwestern parts where glacial erratics are most common. Most accumulations of these pebbles and cobbles are probably lag deposits of the coarser fractions of drift, and a few dense accumulations are mapped as drift.

Most of the drift shown on the geologic map may be remnants of outwash deposits. Some of the very thin deposits, particularly those described as accumulations of scattered cobbles and pebbles, may be till winnowed of fine material. The drift in secs. 13, 14, 23, and 24, T. 139 N., R. 89 W., and secs. 19 and 20, T. 139 N., R. 88 W. (pl. 1), are remnants of deposits of a southeastward-flowing ice-marginal stream or stream system at the front of a northeastward-retreating ice front. Generally, the long axes of these deposits trend southeast to east-southeast, subparallel to the Elm Creek trench, and the general altitudes of the deposits decrease toward the southeast. The drift in secs. 1, 11, 12, and 13, T. 138 N., R. 89 W., and sec. 7, T. 138 N., R. 88 W., in the Tavis Creek drainage and most of the drift in secs. 9, 15, and 22, T. 138 N., R. 88 W., in the Spring Valley Creek drainage are probably remnants of outwash and inwash(?) deposits formed during the retreat of the ice front across a preglacial segment of the South Fork trench. The abundance of drift, including erratics, on high ground near the south boundary of the quadrangle indicates that a stillstand of the ice front occurred near the present position of the Big Muddy-Heart Butte drainage divide.

Alluvium

Alluvium consists of sand, silt, and clay derived from erosion of the Fort Union Formation and the glacial deposits and is mostly of Holocene age. The alluvium in the valleys of Haymarsh and Big Muddy Creeks is at least 30-40 feet thick. Most of the alluvium mapped in the drainages tributary to Haymarsh and Big Muddy Creeks 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 the Haymarsh and Big Muddy Creek valleys probably overlies thick glacial deposits of the former Elm Creek and South Fork trenches. In the Elm Creek trench in southern Mercer County the average thickness of Quaternary fill is about 220 feet, of which only about 30-40 feet is alluvium of Holocene age (M. G. Croft, oral commun., Mar. 11, 1970). According to Henry Trapp (oral commun., Mar. 11, 1970), a hole drilled in the South Fork trench near Richardton in eastern Stark County, about 25 miles west of Glen Ullin, intersected about 280 feet of Quaternary fill.

STRUCTURE

The quadrangle is on the southeastern flank of the Williston basin. In the southern part of the quadrangle the Fort Union strata dip 20-40 feet per mile in a northerly direction away from a poorly defined structural high south of Spring Butte. Local dips on some lignite beds that crop out just south of Big Muddy Creek and along the sides of the valleys of Tavis and Spring Valley Creeks appear higher than this and are probably the result of camber of the lignite beds into the valleys. In the northwestern part of the quadrangle the Fort Union strata appear to dip northeast 20-30 feet per mile toward the area northeast of Haymarsh Creek where dips are less than 10 feet per mile.

ECONOMIC GEOLOGY

Lignite

Lignite beds and zones

Lignite beds in the Fort Union Formation are shown on the geologic map (pl. 1) and in a series of stratigraphic sections (pls. 2 and 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). Lignite beds found only in the drill holes and those in sections measured outside the quadrangle are unnamed.

In general, all beds 1 or more feet thick were mapped. The thickest outcropping beds are 10-12 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.

Three lignite beds that were encountered in the drill hole in sec. 32, T. 139 N., R. 88 W., but that do not crop out in the Glen Ullin quadrangle are shown on plate 2 near the base of the columnar section of the drill hole. One or both of the lowest two may be equivalent to Stephens' (1970a, b) Shell lignite bed.

Lignite beds occur in many parts of the 265- to 305-foot interval of the Fort Union Formation exposed in the Glen Ullin 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 commonly occurs 20-40 feet below the top of the Tongue River Member in the Glen Ullin quadrangle. The thickest outcrops of this bed are in the Tavis Creek drainage where 11.5 feet in a single bed was measured near the east edge of the NW¼SE¼ sec. 11, T. 138 N., R. 89 W. (strat. sec. 17, pl. 2). Locally, instead of a single bed, two beds which are less than 5 to more than 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 generally a carbonaceous shale or thin lignite bed, 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, Hancock's (1921) C bed, and Smith's (1966) Crooked Creek bed. L. P. Dove (in Leonard and others, 1925, p. 136) also correlated the bed mapped in this report as the Tavis Creek with Hancock's (1921, p. 13) C 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 and Dengate quadrangles, and the zone can be recognized in parts of the Heart Butte, North Almont, and New Salem quadrangles. In the Glen Ullin quadrangle the zone commonly contains one bed 5-10 feet thick or two to four beds 1-4 feet thick (pls. 2 and 3). 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., of the Glen Ullin quadrangle. It was mapped in that part of the Glen Ullin quadrangle south of Big Muddy Creek and at a few places near the west edge of the Dengate quadrangle. The Spring Valley bed is thickest in the southeastern part of the quadrangle where single-bed thicknesses of about 8-10 feet are common. Leonard, Babcock, and Dove (1925, fig. 12) show the bed mined in the Spring Valley mine to be approximately 12 feet thick. 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 7-8 feet thick. The Richter bed was mapped extensively in the Dengate quadrangle but only locally in the northeastern part of the Glen Ullin quadrangle where it has been mostly burned.

The Spring Valley and Richter beds are at least partly equivalent, although the Richter bed in most of the Dengate quadrangle appears to be stratigraphically closer to the base of the Sentinel Butte than does the Spring Valley bed in the Glen Ullin quadrangle. The bed mapped as the Richter bed near Twin Buttes in the northwestern part of the Dengate quadrangle and the one mapped as the Spring Valley bed on the buttes just south of Glen Ullin are approximately equivalent to Hancock's (1921, p. 13) D bed, correlations which were originally made by Dove (in Leonard and others, 1925, p. 135-136). In most of the northern part of the Glen Ullin quadrangle (pl. 3) and in a few places in the southwestern part (strat. secs. 1 and 2, pl. 2), the Spring Valley-Richter zone contains two to four lignite beds 1 to more than 6 feet thick, none of which could be traced very far. In these areas each bed of the zone was generally mapped as a local bed of the Spring Valley-Richter zone. In the valley of Haymarsh Creek one of these local beds near the base of the zone was designated the Haymarsh Creek bed (strat. secs. 45, 46, 50, 52, and 58, pl. 3). In the northern part of the area a thin bed of silicified carbonaceous shale or, less commonly, of carbonaceous shale or lignite, which generally crops out at or near the top of the Spring Valley-Richter lignite zone, was mapped as a marker for the approximate position of the top of the zone. The bed mapped may not be exactly the same bed everywhere but could be one of two or three similar beds that occur within a stratigraphic interval less than 15 feet thick.

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 15-20 feet below the Tavis Creek bed, local beds between the Spring Valley-Richter zone and the white siltstone marker, and local beds above the white siltstone marker. The local beds above the white siltstone sequence occur only on a few of the highest buttes of the area but appear to belong to a persistent interval of lignite beds that can be recognized on some high buttes to the west and in the Dengate quadrangle to the east.

Physical and chemical characteristics

The lignite in the Fort Union Formation in the Glen Ullin quadrangle is commonly blackish brown, hard, and woody and is slabby when freshly dug. It characteristically slacks rapidly when exposed to the atmosphere, and outcrop surfaces tend to be granular.

Core samples of each of four 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 Analytical Laboratories are presented in table 1.

Outcrop samples of lignite from the Glen Ullin quadrangle were collected during the summer of 1966 by J. D. Vine, U.S. Geological Survey, assisted by the author. Most of the results of the spectrographic analyses of these samples are given in table 2 with Vine's permission.

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 composition of the ash of four lignite core samples (table 1c) and of nine lignite outcrop samples (table 2) from the Glen Ullin quadrangle is given in terms of selected major and minor elements as determined by semiquantitative spectrographic analysis. Omitted were (1) most of those minor elements not detected in any of the samples, (2) potassium, which was looked for only in each of the four core samples, and (3) silicon which was looked for only in the outcrop samples.

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).

TABLE 1. Analyses of lignite samples from drill cores of the Fort Union Formation, Glen Ullin quadrangle, Morton County, N. Dak.

a. Standard coal analysis (partial)

[Analyses by U.S. Bureau of Mines, Pittsburg, Pa. All analyses are for samples on an as-received basis; volatile matter determined by modified method]

Field No.	Location of drill hole	Sample interval depth (ft)	Lignite bed sampled	Fort Union Formation Member	USBM Lab. No.	Analyses, in percent: Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value (Btu)
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	Sentinel Butte	I-42080	42.7	24.6	26.4	6.3	0.8	6,140
GUC-2-1--	SE¼NE¼ sec. 32, T. 139 N., R. 88 W.	162.6-166.4	Unnamed	Tongue River	I-42083	39.1	25.9	27.2	7.8	0.7	6,490
GUC-3-1--	SW¼SE¼NW¼ sec. 10, T. 139 N., R. 88 W.	65.2-67.3	Haymarsh Creek	Sentinel Butte	I-42088	37.6	26.1	25.8	10.5	0.6	6,400
GUC-3-2--	SW¼SE¼NW¼ sec. 10, T. 139 N., R. 88 W.	85.0-89.6	Tavis Creek(?)	Tongue River	I-42091	38.9	24.1	25.6	11.4	0.5	6,020

b. MgO, CaO, Na_2O, K_2O, and eU in lignite (percent)

[Analyses by U.S. Geological Survey, Denver, Colo. MgO, CaO, Na_2O, and K_2O determined by atomic absorption by Wayne Mountjoy; eU determined by Beta Gamma Scaler by Johnnie Gardner]

Field No.	USGS Lab. No.	MgO	CaO	Na_2O	K_2O	eU
GUC-1-1	D137670	0.46	1.29	0.36	0.02	<0.001
GUC-2-1	D137671	0.50	1.69	1.27	0.04	0.001
GUC-3-1	D137672	0.65	1.48	1.26	0.10	0.001
GUC-3-2	D137673	0.54	1.35	1.29	0.22	<0.001

c. Abundance of selected major and minor elements in lignite ash

[Percent ash determined by ignition method by G. D. Shipley and V. M. Merritt, U.S. Geological Survey. Semiquantitative spectrographic analyses by B. W. Lanthorn, U.S. Geological Survey. Results are based on their identity with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, and so forth, and are reported arbitrarily as midpoints of these brackets, 1., 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, respectively. The precision of a reported value is approximately plus or minus one bracket at 68-percent, or two brackets at 95-percent confidence. Approximate usual lower limits of detection for Ag is .00005; Be .0001; Co .0003; La .003; Nb .001; Pb .001; Sc .0005; Sn .001; Y .001; Zn .02; Ga .0005; Ge .001; Li .005; Yb .0001. Figures in percent by weight. G, greater than 10 percent; N, not detected; L, detected but below value shown]

Field No.	Ash in sample	Major elements: Al	Fe	Mg	Ca	Minor elements: Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	Ga	Ge	Li	Yb
GUC-1-1	20.0	1.5	G	1.5	5.0	.07	.03	N	.07	.3	N	N	.0007	.003	N	.0010	L.002	.001	N	L.001	N	.15	.005	L.002	N	.01	L.001	N	N	.0002
GUC-2-1	11.5	10.0	5.0	2.0	G	.3	.03	N	.15	.7	.0015	.002	.007	.03	N	.0070	.002	.003	.007	.005	N	.7	.020	.030	N	.03	.007	N	N	.0020
GUC-3-1	17.3	10.0	7.0	5.0	7.0	.15	.03	N	.10	.07	.0020	.003	.007	.01	N	.0020	.003	.005	.007	.005	N	.15	.010	.015	N	.03	.007	N	N	.0015
GUC-3-2	16.0	7.0	3.0	5.0	7.0	.3	.03	N	.10	.10	.0010	.002	.005	.007	N	.0015	.003	.003	.003	.003	N	.20	.015	.010	N	.05	.005	N	N	.0010

TABLE 2.--Abundance of selected major and minor elements in ash of lignite outcrop samples from the Glen Ullin quadrangle, Morton County, N. Dak.

[Samples collected by J. D. Vine, assisted by C. S. V. Barclay. Semiquantitative spectrographic analyses by A. L. Sutton, Jr. Results are based on their identity with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, and so forth, and are reported arbitrarily as midpoints of these brackets, 1., 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, respectively. The precision of a reported value is approximately plus or minus one bracket at 68-percent, or two brackets at 95-percent confidence. Approximate usual lower limits of detection for Ag is .00005; Be .0001; Co .0003; La .003; Nb .001; Pb .001; Sc .0005; Sn .001; Y .001; Zn .02; Ga .0005; Ge .001; Li .005; Yb .0001. Figures in percent by weight. G, greater than 10 percent; N, not detected; --, not looked for.]

Field No.	Location	Lignite bed sampled	Fort Union Formation Member	USGS Lab. No.	Ash in sample	Al	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	V	Y	Zn	Zr	Ga	Ge	Li	Yb
-490	Roadcut, SE¼SE¼ sec. 18, T. 139 N., R. 88 W.	Local bed, 1.5 ft thick, approximately 20 ft above Spring Valley-Richter lignite zone.	Sentinel Butte	D124847	16.6	G	G	5.0	G	.20	.015	N	--	0.05	.002	.01	.007	.02	.015	.007	.001	.1	.005	--	N	.15	.02	.02	N	--	--	--	N	--
-492A	Roadcut, SW¼SW¼SE¼ sec. 35, T. 139 N., R. 89 W.	Spring Valley bed, 3.3 ft thick.	--do.	D124849	11.6	7.0	G	2.0	G	.15	.07	.0001	--	0.3	.001	.01	.005	.007	.005	.0015	.001	.015	.005	--	N	.30	.01	.015	.07	--	--	--	N	--
-493A	Roadcut, SE. cor. SE¼NE¼SE¼ sec. 11, T. 138 N., R. 89 W.	Tavis Creek bed; 6-in. interval at top of 11.5-ft bed.	Tongue River	D124851	24.2	7.0	5.0	5.0	7.0	.20	.03	.0002	--	1.0	.0007	.0007	.003	.005	.003	.0015	.002	.005	.02	--	N	.30	.007	.007	N	--	--	--	N	--
-493B	------do.	Same bed as 493A; 6-in. interval 2-2½ ft below top of bed.	--do.	D124852	15.6	G	1.5	5.0	5.0	.20	.07	N	--	0.7	.0002	.0003	.002	.005	.003	.0015	.0015	.0015	.005	--	N	.15	.007	.003	N	--	--	--	N	--
-493C	------do.	Same bed as 493A and B; 6-in. interval 3½-4 ft below top of bed.	--do.	D124853	25.2	G	3.0	2.0	3.0	.50	.10	N	--	1.0	.0002	.0005	.005	.01	.01	.001	.002	.001	.007	--	N	.10	.01	.005	N	--	--	--	N	--
-494A	Roadcut, SE¼NE¼SE¼ sec. 23, T. 138 N., R. 89 W.	Local bed in Spring Valley-Richter lignite zone; 6-in. interval at top of 8.9-ft lignite bed.	Sentinel Butte	D124854	11.4	G	G	1.5	7.0	.30	.03	N	--	1.0	.0007	.01	.015	.02	.015	.002	.002	.05	.007	--	N	.30	.02	.015	N	--	--	--	N	--
-494B	------do.	Same bed as 494A; interval 3-3½ ft below top of bed.	--do.	D124855	11.6	7.0	7.0	1.5	G	.07	.05	N	--	0.2	.0005	.007	.007	.01	.01	.002	N	.03	.002	--	N	.30	.02	.01	N	--	--	--	N	--
-494C	------do.	Same bed as 494A and B; interval 8.0-8.8 ft below top of bed.	--do.	D124856	7.5	G	7.0	7.0	G	.10	.20	N	--	1.0	.0015	.01	.002	.005	.005	.001	N	.02	.003	--	N	.50	.005	.015	.10	--	--	--	N	--
-495A	Coulee bank, N½SW¼SE¼ sec. 32, T. 139 N., R. 88 W.	Local bed approximately 25 ft below base of Tavis Creek bed.	--do.	D124857	20.0	7.0	5.0	3.0	5.0	.30	.05	N	--	0.7	.001	.001	.01	.007	.003	.002	.0015	.005	.007	--	N	.15	.015	.01	N	--	--	--	N	--

The percent 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 not excessive for lignite containing 2 percent Na_2O in ash, but they increase markedly for lignite with 4½ percent Na_2O in ash and are excessive for lignite with 9 percent Na_2O in ash. Table 1b shows amounts of magnesium, calcium, sodium, and potassium oxides in the lignite core samples. Using the percentage of ash given in table 1c, the calculated percentage of sodium oxide in ash for each sample in order of appearance in table 1b is 1.8, 7.3, 8.1, and 11.0. All but the sample of the Spring Valley bed have sodium contents characteristic of lignite that has a high fouling potential. 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 four 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). The minerals detected were quartz, pyrite, montmorillonite, kaolinite, calcite, gypsum, anhydrite(?), siderite(?), albite(?), and orthoclase(?). No mineral containing sufficient sodium to account for the amounts that were detected in the ash could be found. 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).

Development

Lignite beds in the Glen Ullin quadrangle were mined, principally for local use, in the past. Most of the mining was done in the late 1800's and the early 1900's. Some of the early mining supplied the needs of the locomotives of the Northern Pacific Railroad. Most of the mining activity ceased before World War II, and none of the mines are active now.

Most of the lignite mined was from the Tavis Creek or Spring Valley beds, but the Haymarsh Creek beds were mined in secs. 8 and 9, T. 139 N., R. 88 W., and a local bed approximately equivalent to Stephens' (1970a) Kit Fox bed was mined in sec. 20, T. 138 N., R. 88 W.

Mine workings were usually small shallow open pits. A few underground mines were found, but all were caved and the portal at most sites could be only approximately located. The Tavis Creek bed was probably mined by slopes in sec. 20, T. 139 N., R. 88 W., and sec. 25, T. 139 N., R. 89 W. The Spring Valley Products Co. mined the Spring Valley bed by underground workings in secs. 21 and 22, T. 138 N., R. 88 W., with extensions into sec. 27 and possibly sec. 28. The main opening in sec. 22 was connected by a spur (now dismantled) to the Northern Pacific Railroad east of Glen Ullin.

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. The gravel supply at the pit sites in the drift in the SE¼ sec. 14 and the NE¼ sec. 24, T. 139 N., R. 89 W., and the SW¼ sec. 22, T. 138 N., R. 88 W., has been largely exhausted, and the pits were inactive during the course of fieldwork for this project.

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). Some of the burning in the Glen Ullin quadrangle probably occurred during Holocene time; clinker flakes in the drift in sec. 14, T. 139 N., R. 89 W., indicate that at least some took place during Pleistocene time. Clinker is abundant in the southern part of the quadrangle, and the thickest deposits are associated with the Spring Valley lignite bed. Clinker is used extensively by local individuals and county road crews to surface roads.

Ganister blocks

Areas containing concentrations of scattered ganister blocks are shown on plate 4. Plate 4 is a print of an overlay to be used with the geologic map.

Ganister blocks are angular cobble- and boulder-sized blocks and boulder-sized 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. The largest blocks have dimensions of 10 x 5 x 3 feet and occur in the southern part of sec. 22, T. 138 N., R. 88 W. A thin section of a sample of a block found near the west end of Rocky Ridge is primarily composed of silt-sized quartz grains in a matrix of interlocking microcrystalline quartz and is similar to what Milner, Ward, and Higham (1962, p. 222-223) described as ganister. Some of the blocks may be glacial erratics or lag deposits of glacial drift. Angular cobble- and pebble-sized fragments of ganister are in some of the drift, 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. Thin beds of partly silicified sandy carbonaceous mudstone and sandy siltstone containing small carbonized plant rootlets or stems are associated with some carbonaceous shale or lignite beds in the Sentinel Butte in the Rocky Ridge area (strat. secs. 12 and 13, pl. 2) where ganister blocks are most abundant. Denson and Pipiringos (1969, p. 15) reported that beds in part of Wyoming and North Dakota that they and others have described as beds of silicified swamp muck, quartzite, or ganisterlike rock appear to occur only in the Paleocene formations.

In North Dakota ganister blocks have been widely used for riprapping earthfill dams, water diversion channels, and river banks. Ganister blocks have also been used locally in the construction of small farm buildings.

Oil and gas

No test wells for oil and gas have been drilled in the Glen Ullin quadrangle. The closest producing well is about 20 miles west of Glen Ullin 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 (North Dakota Geological Survey, 1969, p. 24). Rocks at depth in the Glen Ullin quadrangle are prospectively valuable for oil and gas. The sedimentary section underlying the area is probably more than 10,000 feet thick (Hansen, 1957) and 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 (North Dakota Geological Survey, 1969). The slight structural high south of Spring Butte should be geophysically explored to determine if it is a reflection of a structure in the pre-Tertiary rocks.

REFERENCES CITED

Anderson, S. B., and Mendoza, H. A., 1960, Pre-Mesozoic paleogeologic map of North Dakota: N. Dak. Geol. Survey Misc. Map 7.

Benson, W. E., 1953, Geology of the Knife River area, North Dakota: U.S. Geol. Survey open-file report, 323 p., also Ph. D. thesis, Yale Univ.

Blain, W. S., 1955, "Scoria" of North Dakota: N. Dak. Geol. Survey Bull. 28, p. 138-143.

Brown, R. W., 1962, Paleocene flora of the Rocky Mountains and Great Plains: U.S. Geol. Survey Prof. Paper 375, 119 p.

Carlson, C. G., compiler, 1969, Bedrock geologic map of North Dakota: N. Dak. Geol. Survey Misc. Map 10.

Colton, R. B., Lemke, R. W., and Lindvall, R. M., 1963, Preliminary glacial map of North Dakota: U.S. Geol. Survey Misc. Geol. Inv. Map I-331.

Denson, N. M., and Pipiringos, G. N., 1969, Stratigraphic implications of heavy-mineral studies of Paleocene and Eocene rocks of Wyoming, in Wyoming Geol. Assoc. Guidebook, 21st Ann. Field Conf., Symposium on Tertiary rocks of Wyoming, 1969: p. 9-18.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., Inc., 534 p.

Gluskoter, H. J., 1965, Electronic low-temperature ashing of bituminous coal: Fuel, v. 44, no. 4, p. 285-291.

Gronhovd, G. H., 1968, Progress and problems in combustion of lignite from the northern Great Plains area [preprint]: New York, Soc. Mining Engineers, AIME, 15 p.

Gronhovd, G. H., Harak, A. E., and Paulson, L. E., 1968, Ash fouling studies of North Dakota lignite: U.S. Bur. Mines Inf. Circ. 8376, p. 76-94.

Hancock, E. T., 1921, The New Salem lignite field, Morton County, North Dakota: U.S. Geol. Survey Bull. 726-A, p. 1-39.

Hansen, Miller, 1957, Structure map on pre-Cambrian [North Dakota]: N. Dak. Geol. Survey Misc. Map 5.

Hickey, L. J., 1969, Stratigraphy of the Golden Valley Formation of western North Dakota [abs.]: Geol. Soc. America Abs. with programs for November 1969, p. 100.

Laird, W. M., and Mitchell, R. H., 1942, The geology of the southern part of Morton County, North Dakota: N. Dak. Geol. Survey Bull. 14, 42 p.

Leonard, A. G., 1916, Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., v. 27, p. 295-304.

Leonard, A. G., Babcock, E. J., and Dove, L. P., 1925, The lignite deposits of North Dakota: N. Dak. Geol. Survey Bull. 4, 240 p.

Milner, H. B., Ward, A. M., and Higham, Frank, eds., 1962, Sedimentary petrography--v. 2, Principles and applications [4th ed.]: New York, Macmillan Co., 715 p.

North Dakota Geological Survey, 1969, Production statistics and engineering data; oil in North Dakota, first half 1969: Grand Forks, N. Dak. Geol. Survey, 164 p.

Royse, C. F., Jr., 1967, Tongue River-Sentinel Butte contact in western North Dakota: N. Dak. Geol. Survey Rept. Inv. 45, 53 p.

______1970, A sedimentologic analysis of the Tongue River-Sentinel Butte interval (Paleocene) of the Williston Basin, western North Dakota: Sedimentary Geology, v. 4, no. 1, p. 19-80.

Seager, O. A., and others, 1942, Stratigraphy of North Dakota: Am. Assoc. Petroleum Geologists Bull., v. 26, no. 8, p. 1414-1423.

Smith, H. L., 1966, Geologic map of the New Salem quadrangle, Morton County, North Dakota: U.S. Geol. Survey open-file map.

______1970, Preliminary description of cores, chemical analysis of lignite beds, and map showing locations of holes drilled in Grant, Hettinger, Morton, and Stark Counties, North Dakota: U.S. Geol. Survey open-file report, 43 p.

Sondreal, E. A., Kube, W. R., and Elder, J. L., 1968, Analysis of the Northern Great Plains Province lignites and their ash: a study of variability: U.S. Bur. Mines Rept. Inv. 7158, 94 p.

Spencer, J. D., 1969, Review of Bureau of Mines coal program, 1968: U.S. Bur. Mines Inf. Circ. 8416, 94 p.

Stephens, E. V., 1970a, Geologic map of the Heart Butte NW quadrangle, Morton and Grant Counties, North Dakota: U.S. Geol. Survey Coal Inv. Map C-52. [In press]

______1970b, Geologic map of the Heart Butte quadrangle, Morton and Grant Counties, North Dakota: U.S. Geol. Survey Coal Inv. Map C-53. [In press]

Tisdale, E. E., 1941, The geology of the Heart Butte quadrangle; N. Dak. Geol. Survey Bull. 13, 32 p.

Zubovic, Peter, Stadnichenko, Taisia, and Sheffey, N. B., 1961, Geochemistry of minor elements in coals of the Northern Great Plains coal province: U.S. Geol. Survey Bull. 1117-A, p. A1-A58.