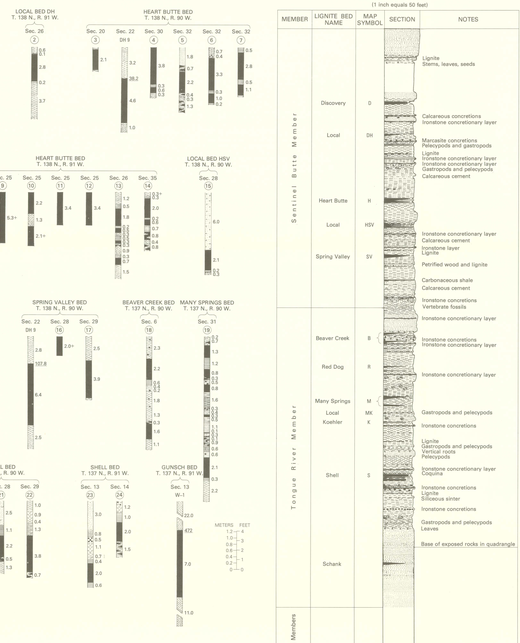
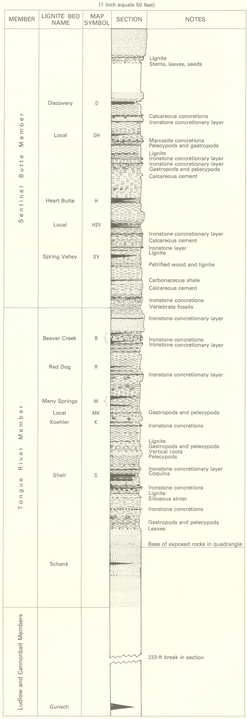
LIGNITE SECTIONS

Note: Underlined numbers show depth (feet) from ground surface to top of lignite bed



COMPOSITE COLUMNAR SECTION OF PART OF THE FORT UNION FORMATION

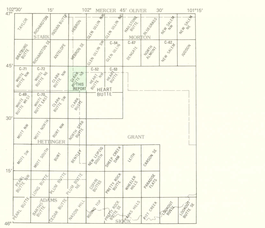
(1 inch equals 50 feet)

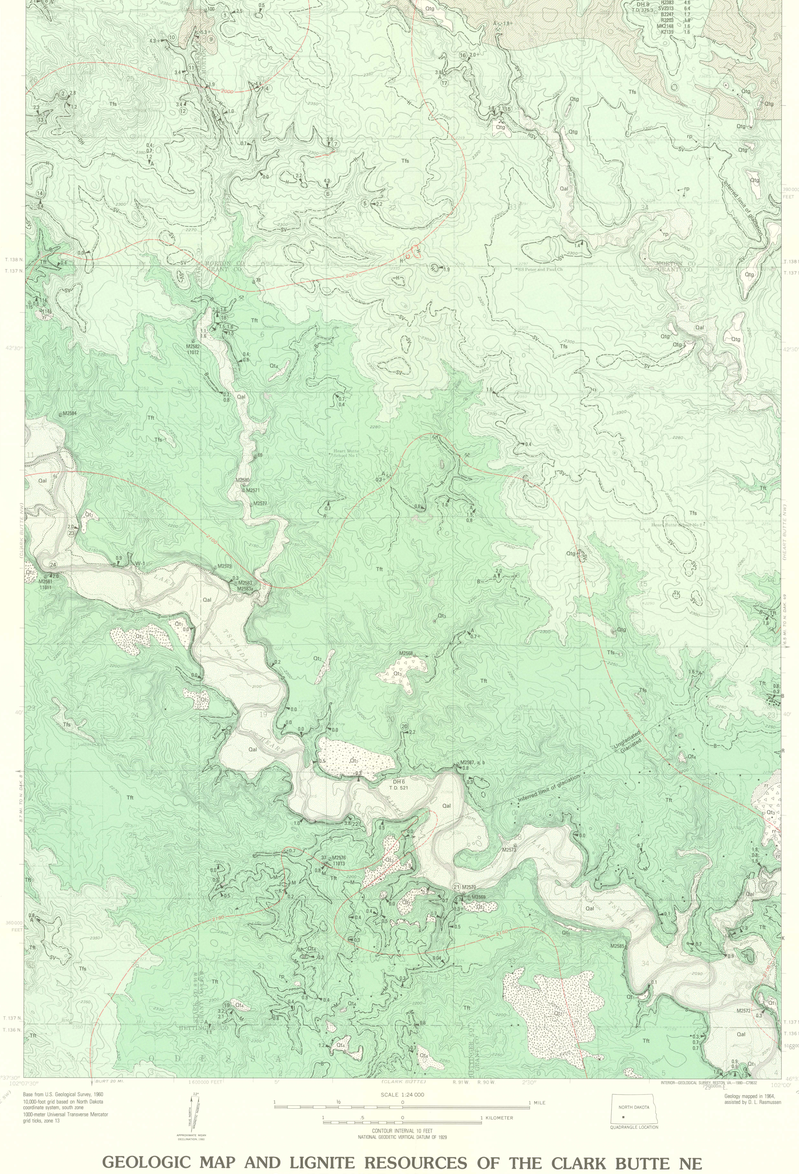


EXPLANATION

Sand and gravel
Sandstone
Siltstone
Clayey siltstone
Mudstone
Claystone
Brown carbonaceous mudstone
Brown carbonaceous siltstone
Lignite
Impure lignite
Lignitic
Ferruginous or ironstone concretions
Calcareous concretions
Calcareous
Fresilized plants
Fossil nonmarine animals
Covered
Location shown on map

INDEX OF PART OF SOUTHWESTERN NORTH DAKOTA—SHOWING CLARK BUTTE NE QUADRANGLE, QUADRANGLE NAMES, AND NUMBERS OF RECENTLY PUBLISHED U.S. GEOLOGICAL SURVEY COAL INVESTIGATIONS MAPS





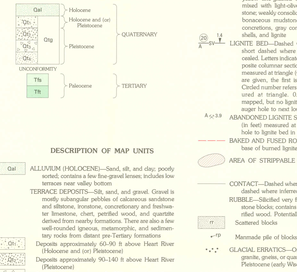
Base from U.S. Geological Survey, 1960
10,000-foot grid based on North Dakota coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

Geology mapped in 1984, assisted by D. J. Rasmussen

GEOLOGIC MAP AND LIGNITE RESOURCES OF THE CLARK BUTTE NE QUADRANGLE, NORTH DAKOTA

By
George D. Mowat
1980

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qal ALLUVIUM (HOLOCENE)—Sand, silt, and clay; poorly sorted; contains a few fine-gravel lenses; includes low terraces near valley bottom

TERRACE DEPOSITS—Silt, sand, and gravel. Gravel is mostly subangular pebbles of calcareous sandstone and siltstone, ironstone, concretionary and freshwater limestone, chert, petrified wood, and quartzite derived from nearby formations. There are also a few well-rounded igneous, metamorphic, and sedimentary rocks from distant pre-Tertiary formations

Qtu Deposits approximately 60-90 ft above Heart River (Holocene and (or) Pleistocene)

Qtm Deposits approximately 90-140 ft above Heart River (Pleistocene)

Qtl Deposits approximately 140-180 ft above Heart River (Pleistocene)

Qtg Deposits approximately 180-230 ft above Heart River (Pleistocene)

Qtt TERRACE AND GLACIOFLUVIAL DEPOSITS UNDIFFERENTIATED (HOLOCENE AND (OR) PLEISTOCENE)—Gravel, sand, silt, and clay. Gravel is mostly angular, poorly sorted imbricate cobbles and pebbles of limestone, quartzite, ironstone, petrified wood, and sandstone derived from local formations. There are a few igneous, metamorphic, and sedimentary rocks from distant pre-Tertiary formations

Tfu FORT UNION FORMATION (PALEOCENE)
Sentinel Butte Member—Yellowish-gray fine-grained sandstone and siltstone interwoven with light-olive-gray claystone; weakly consolidated. Also contains brown carbonaceous mudstone, yellowish-brown ironstone concretions, gray concretionary limestone, petrified wood, lignite, and silicified siltstone and claystone

Tfl Tongue River Member—Yellowish-gray to grayish-yellow fine-grained sandstone and siltstone interlayered with light-olive-gray to yellowish-gray claystone; weakly consolidated. Also contains brown carbonaceous mudstone, yellowish-brown ironstone concretions, gray concretionary limestone, mollusk shells, and lignite

Tfr LIGNITE BED—Dashed where approximately located; short dashed where inferred; dotted where concealed. Letters indicate lignite bed named in the composite columnar section. Thickness of lignite, in feet, measured at triangle (where two or more thicknesses are given, the first is the highest stratigraphically). Underlined numbers in plotted lignite section measured at triangle. 0.0 indicates lignite horizon mapped, but no lignite is present; A indicates hand-auger hole to base of lowest lignite

INTRODUCTION

The Clark Butte NE quadrangle was mapped in 1964 as part of the U.S. Geological Survey's program of classifying and evaluating Federal mineral lands. During the summer of 1966, test holes were drilled to determine the quality, thicknesses, and extent of lignite beds in the Fort Union Formation of Paleocene age.

STRATIGRAPHY

About 540 ft of uppermost Fort Union strata is exposed in this quadrangle. Subsurface sedimentary rocks, ranging in age from Cambrian to Paleocene, total about 11,300 ft (Benson and Gill, 1965, p. 5). Surficial deposits comprise terrace deposits, alluvium, glacial erratics, baked and fused rock associated with burned lignite beds, and siliceous rubble.

FORT UNION FORMATION

The Fort Union Formation is estimated to be about 1,370 ft thick in this quadrangle and comprises four members, in ascending order the Ludlow, Cannonball, Tongue River, and Sentinel Butte. The Cannonball Member is marine; other members are nonmarine and lignite bearing. Only the two uppermost members are exposed.

Ludlow and Cannonball Members.—These members probably interfinger beneath this quadrangle and they are not readily distinguishable on the basis of drill-hole information. The combined Ludlow and Cannonball Members are estimated to be 685 ft thick; they are composed of soft, fine-grained yellowish-gray sandstone, medium- to coarse-grained light-olive-gray sandstone that contains abundant dark grains, poorly sorted light-olive-gray siltstone and mudstone, and lignite. In areas of outcrop to the south and east of the quadrangle, the members can be identified by the presence of marine fossils in the Cannonball and by the presence of lignite and nonmarine fossils in the Ludlow. The Ludlow rests conformably on the Cretaceous Hell Creek Formation and is locally channeled and overlain by a conglomerate of the Tongue River Member (Lloyd and Hares, 1915, p. 538). The Ludlow and Cannonball are deltaic deposits of early and perhaps middle Paleocene age (Pearson and Tomiyasu provincial age; Wood and others, 1941). D. W. Taylor (U.S. Geological Survey, 1967, p. A119-A120) dated freshwater mollusks collected about 140 ft above the base of the overlying Tongue River Member as middle or, perhaps, early Paleocene. Nine samples from drill hole DH6 in sec. 29, T. 137 N., R. 90 W., were examined by R. H. Tschudy for palynomorphs. Tschudy reported that Kurtzipites is a genus present in Upper Cretaceous rocks and it persists into the lower Tertiary Tschudy Member (equivalent to lower part of Ludlow Member). *Kurtzipites* has not been found in middle or upper Paleocene rocks. Therefore, at least the lowest 126 ft of strata in drill hole DH6 is no younger than early Paleocene, based on the presence of *Kurtzipites* in samples from 395 to 515 ft. The top of the Ludlow or Cannonball is interpreted to be at 130 ft depth at the top of a clayey siltstone beneath the basal sandstone of the Tongue River Member. Tschudy reported marine hystrichosphereas, dinoflagellates, and Pterospermopsis present in samples from 175 to 515 ft. (The interval from 130 to 175 ft was not tested for palynomorphs.) Because these marine forms are sparse, Tschudy suggested that deposition was deltaic or at least very near shore. Therefore, the interval from 130 to 515 ft cannot definitely be assigned to the Cannonball Member.

Tongue River Member.—About 250 ft of the 310-ft-thick Tongue River Member crops out in this quadrangle. It is predominantly alternating clayey siltstone, silty claystone, and sandstone. Less abundant are lignite, brown carbonaceous mudstone, ferruginous concretions, and concretionary freshwater limestone. The predominant color is light olive gray to yellowish gray. Lithology varies both laterally and vertically, and sandstone bodies locally fill channels cut into older beds. (See composite columnar section.)

At the base of the Tongue River Member is a widespread sandstone, which averages about 100 ft in thickness east of the quadrangle (Trebelle, 1962, p. 10). The base of this sandstone is not exposed in the quadrangle. The sandstone is interpreted to be 130 ± 30 ft thick in drill hole DH6; the upper 50 ft at least is absent in the SW¼NW¼SE¼ sec. 34, T. 137 N., R. 90 W.

About 1.25 ft above the Shell lignite bed is a distinctive coquina, consisting of small 0.5-in. pelecypods *Corbula mactriformis* Meek and Hayden, and larger gastropods. This yellowish-brown-stained coquina (10 YR 6-6/2-4, Goddard, 1970) was used as a marker bed throughout the quadrangle. Trebelle (1941, p. 11) described this bed in the Heart Butte quadrangle to the east and ascribed its formation to deposition in a lake.

In the eastern part of the quadrangle the beds between the Koehler and Many Springs lignite beds are strikingly more yellow than the beds above and below this sequence. To the west the contrast in color is less.

Mollusk fossils are abundant between the Shell and Many Springs lignites but are scarce above the Many Springs beds. D. W. Taylor (written commun., 1966) made the following report on the basis of mollusks collected by D. L. Rasmussen and G. D. Mowat:

"The association of *Bellamya retusa*, *Campeloma nebracense*, *'Campeloma' limnaeformis*, *Cleopatra nebraska producta*, and *Cleopatra tenuicornata* is found widely in Wyoming, where it is known to be of Torrejonian (mid-Paleocene) age". The lignite level is uncertain; in some areas no older rocks are exposed, and in others no collections already made have not been studied or the necessary fieldwork has not been carried out. As the fauna of the Lance Formation is clearly distinct (from the faunal association), the uncertainty about the lower age limit is early Paleocene (Puercan and early Torrejonian). Within the Powder River Basin, this Torrejonian fauna is found only below the Wall coal bed of the Tongue River Member. These collections from North Dakota are no younger than mid-Paleocene, and evidently correlative with what had been called the lower part of the Tongue River in the Powder River Basin, at the highest.

"Some species from these North Dakota collections have not been found in the Powder River Basin: *Pleisilliptio* n. sp., *Pleisilliptio stantoni* (White), *Pleisilliptio?* sp., *Rhabdoxophorus gracilis* Russell, *Corbula mactriformis* Meek and Hayden, *Bellamya meeki* (Ward), *Bellamya* aff. *B. peculiaris* (Meek and Hayden), and *Hydrobia warrenana* Meek and Hayden. Their presence in the North Dakota collections may indicate a lower stratigraphic position and (or) difference in environment."

The fauna just listed was collected from the interval from the Shell lignite bed to 88 ft above this bed (approximately 140-228 ft above the base of the Tongue River Member). *Bellamya retusa*, *"Campeloma" limnaeformis*, and *Cleopatra nebraska producta* were also collected 285 ft above the base of the Tongue River Member. Table 1 lists fossils collected from the Tongue River.

The Tongue River contains rocks containing sandstone and siltstone channel fillings deposited in a flood-plain environment; lignite, claystone, limestone, and laminated siltstone were deposited in a swamp; and clayey siltstone formed as overbank deposits.

Sentinel Butte Member.—The lower 290 ft of the Sentinel Butte Member is present in the quadrangle. The member may have originally been as much as 375 ft thick.

Lithologically the Sentinel Butte resembles the underlying Tongue River; however, its basal 40-60 ft tends to be darker and grayer. A distinctive basal sandstone described by Royse (1967, p. 7, 12-14) along the Little Missouri River may be present in the quadrangle and occur about 50 ft above the Shell lignite bed. This sandstone is very white biotite and pieces of very fine grained sandstone or siltstone in basal beds. A thin, dark-olive-gray bentonitic siltstone locally overlies the lower contact. Fragments of lignite and carbonaceous zones associated with this bentonite may represent the HT Butte lignite bed (Royse, 1967, p. 5).

In contrast to the nonsilicified Tongue River, the Sentinel Butte is silicified throughout. Platy silicified lignite, petrified wood, upright stumps, siltstone, mudstone, and swamp deposits imprinted with abundant plant fragments are common. Hanes (1928, p. 34-36) discussed siliceous beds in detail.

The Sentinel Butte has fewer mollusk fossils than the Tongue River but abundant vertebrates such as Crocodilus, *Champsosaurus*, and turtles near its base (table 2).

[1]The use of these generic terms reflects Taylor's opinion regarding the synonymy of Cleopatra and Lagrossula and his inclusion of all species of North American Bellamyinae within the genus Bellamya. This statement may be incorrect as applied to Cleopatra tenuicornata (J. H. Hanley, written commun., 1974).

ECONOMIC GEOLOGY

LIGNITE

Ten named and three local lignite beds are present beneath the quadrangle. The lowermost of these, the Gunsch bed, occurs about 470 ft below the Shell bed, and the inferred Schanks bed may be present about 90 ft below the Shell bed in the northwest corner of the quadrangle. The Heart Butte and Spring Valley beds in the northern part of the quadrangle have the best potential for future mining.

Physical and chemical properties.—Lignite samples from drill holes in or near the quadrangle were analyzed (table 4). The lignite is dark brown to black and has a brown streak; it is predominantly attrital with lenses of woody-textured preovitrain. Fusain is a minor constituent. When fresh, the lignite is hard and brittle, but when exposed to air, the lignite slacks or loses moisture and disintegrates into small pieces. Gypsum, jarosite, marcasite or pyrite, and pertrigo of claystone and siltstone occur in the coal. Parts of some lignite beds have been weathered to leonardite.

Lignite from the Heart Butte bed in drill hole DH9 has 10 percent ash, 0.09 percent mercury, 0.53 weight percent MgO, 1.72 weight percent CaO, 0.86 weight percent Na_2O, and 0.05 weight percent K_2O (analyses by U.S. Geological Survey, Denver, Colo.).

Thickness and description of lignite beds.—The Shell lignite bed is inferred to be as much as 4 ft thick in the southwestern part of the quadrangle. In secs. 28, 33, and 34, T. 137 N., R. 90 W., the Shell bed is cut out and replaced by channel sandstone. The Spring Valley and Heart Butte beds in the north are as much as 6 ft and 5 ft thick, respectively. Based on the interpretation of a water-well log of uncertain reliability, the Gunsch bed is inferred to be 7 ft thick in the west-central part of the quadrangle.

Lignite resources.—Identified lignite resources totaling 96.2 million short tons (table 5) are in two classes termed (1) demonstrated (measured plus indicated) and (2) inferred. Demonstrated resources lie within ¾ mi from known information points and inferred resources extend from ¾ to 3 mi from points of observation (U.S. Bureau of Mines and U.S. Geological Survey, 1976).

Isopach maps were constructed on each lignite bed at least 2.5 ft thick; areas of demonstrated and inferred resources were delineated; and a further breakdown was made according to thickness categories of 2.5-5 and 5-10 ft. The areas of each category were measured with a planimeter, multiplied by average thicknesses, and then multiplied by a lignite density of 1,750 short tons per acre-ft (1,287 t/m^3).

Strippable deposits.—Areas underlain by at least 5 ft of lignite having less than a 10:1 ratio of overburden to lignite thickness are outlined on the map. The Heart Butte bed meets these criteria beneath parts of secs. 19, 23, 26, 27, and 30, T. 138 N., R. 90 W., and secs. 24 and 25, T. 138 N., R. 91 W. The Spring Valley bed may be amenable to strip mining beneath parts of secs. 20-23 and 26-29, T. 138 N., R. 90 W. Resources of strippable lignite total 7.7 million tons (table 5).

Deposits of rubble in sec. 26, T. 137 N., R. 90 W., are part of more extensive deposits to the east which have a potential use as riprap and rockfill in earthen dams. The material occurs as angular blocks up to several feet long and wide, but mostly less than 1.5 ft thick. These blocks are usually scattered on the ground surface or partially buried. They are extremely resistant to weathering and very hard. Generally they are silicified mudstone or siltstone containing plant fragments or organic debris. A small amount of rubble occurs in sec. 2, T. 137 N., R. 91 W.

GRAVEL

Small amounts of gravel are present in the terrace and glaciofluvial deposits. Because it is covered by finer material in most areas, the gravel in the terrace deposits is not readily available. The glaciofluvial deposits are probably a better source of gravel, although they might require screening for some uses. The gravel is used mainly for surfacing the local graded roads.

CLINKER

Baked and fused rock that formed within and above burned lignite beds is used as road-surfacing material in surrounding areas. Minor amounts of clinker are present in secs. 9 and 14, T. 137 N., R. 90 W., and secs. 31 and 32, T. 138 N., R. 90 W. In the NW¼SE¼ sec. 9, the clinker capping hill 2400 was formed by the burning of the Heart Butte bed. It is too small to be shown at the scale of the geologic map.

OIL AND GAS

The Buffalo Creek oil field (one producing well) lies 7 mi west of this quadrangle. The discovery well, Texaco 1 Schanks, C NW¼SE¼ sec. 15, T. 137 N., R. 92 W., was completed for production November 9, 1966, from 10,216- to 10,226-ft depth in the Red River Formation of Ordovician age. Initial production was 200 barrels of oil per day flowing and 30 barrels of water flowing. The well bottomed at 10,425 ft in the Red River Formation. The field also has two dry holes. Although this quadrangle's surface structure is not particularly favorable for oil and gas, the thick sedimentary section and proximity to an oil field make it potentially valuable for oil and gas.

SALT

The Mississippian *Ø* salt and possibly the Mississippian *I* salt are projected to underlie part of this quadrangle (Anderson and Hansen, 1957, pl. 11, figs. 7, 9). The *Ø* bed, 0 to about 10 ft thick, underlies approximately 7,000 ft of overburden. Thick, extensive deposits of salt occur to the north in the Williston basin.

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GEOLOGIC INVESTIGATIONS

The age of the Sentinel Butte Member is generally accepted as Paleocene. The age of the underlying Tongue River is Paleocene or early Tertiary. The stratigraphically higher Sentinel Butte therefore has an uncertain lower age limit. The overlying Golden Valley Formation is Paleocene and Eocene.

The environment of deposition of the Sentinel Butte was similar to that of the underlying Tongue River. The slightly larger sediment transported as a graded suspension in the Sentinel Butte indicates that Sentinel Butte streams had a slightly higher velocity than Tongue River streams (Royse, 1970, p. 68).

TERRACE DEPOSITS

Four somewhat overlapping terrace deposits occur about 60-90, 90-140, 140-180, and 180-230 ft above the Heart River. The younger terrace deposits (lower terraces) generally have sandy gravel overlain by silty sand or sandy silt. Fine material is less abundant in the older terrace deposits than the younger terrace deposits. The gravel is mostly composed of pebbles less than 1 in. in diameter but locally contains cobbles. Most pebbles are calcareous sandstone and siltstone, ironstone, concretionary and freshwater limestone, chert, petrified wood, and orthoquartzite. The pebbles are somewhat angular and were derived from reworking of local formations. Most of the freshwater limestone fragments were derived from erosion of the Oligocene White River Formation. Other pebbles were derived from the erosion of the Fort Union and Golden Valley Formations. Well-rounded pebbles of quartzite, porphyritic felsic volcanic rock, vein quartz, granite, gneiss, and schist make up 3 percent or less of the pebbles. These well-rounded pebbles may have come from erosion of the basal part of the White River Formation, younger terraces, or reworked glacial deposits.

The terrace deposits are at least 15 ft thick and may be more extensive than shown on the map because the fine material masks the character of the deposits. The lowest terrace deposit is probably younger than the glacial erratics because the few glacial erratics that are on the deposit could have been rolled down nearby bluffs. Abundant glacial erratics on the higher terrace deposits show that they were formed before the glaciation. Clayton (1966, p. 4, 7) suggested that these erratics were derived from the Morton Drift of early or pre-Wisconsinan age. Therefore, the higher terrace deposits are early Wisconsinan or older. Fossils found in the terrace deposits or in alluvium (table 3) are not diagnostic of any precise age in the Quaternary.

UNDIFFERENTIATED TERRACE AND GLACIOFLUVIAL DEPOSITS

The terraces along Beaver Creek are mantled with coarser material than the terraces along the Heart River. The composition of the pebbles, cobbles, and boulders is similar to that of the terrace deposits along the Heart River. Sorting is very poor and imbrication is apparent in some deposits. Probably much of these terrace deposits is made up of glacial outwash mainly of local derivation. These deposits are most likely pencontemporaneous with the Morton Drift.

GLACIAL ERRATICS

Glacial erratics of the Morton Drift are scattered throughout the southeast part of the quadrangle and occur along the Heart River. Most are subangular to subrounded well-rounded boulders of granite, gneiss, or quartzite. Their age is probably early or pre-Wisconsinan (Clayton, 1966, p. 4, 7).

ALLUVIUM

Alluvium of Holocene age mapped along the major drainages is composed chiefly of sand and silt, but includes gravel in river channels and near the base of the deposits.

STRUCTURE

The quadrangle lies about 110 mi S. 30° E. from the center of the Williston basin. Compared to the center of the basin, the top of Precambrian rocks in the quadrangle is about 4,500 ft structurally higher and the top of the Upper Cretaceous Pierre Shale is about 700 ft structurally higher (Denson and Gill, 1965, pl. 5).

Rocks in this quadrangle seem to be flat lying, but they actually dip gently northward 25 ft/mi or about ¼°. The dip is even less in the eastern part of the quadrangle. Structural relief is about 200 ft. A poorly defined anticlinal nose, several miles across, plunges gently to the north.

ECONOMIC GEOLOGY

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