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COUNTY GROUND WATER STUDIES 3

GEOLOGY AND GROUND WATER RESOURCES

of Burleigh County, North Dakota

PART I - GEOLOGY

By
Jack Kume and Dan E. Hansen

GRAND FORKS, NORTH DAKOTA

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THE GEOLOGY OF BURLEIGH COUNTY NORTH DAKOTA

by Jack Kume and Dan E. Hansen

ABSTRACT

Burleigh County in south-central North Dakota lies within the Missouri River Trench, Coteau Slope, and Missouri Coteau physiographic districts of the Glaciated Missouri Plateau section. Subdivisions of the Coteau Slope in Burleigh County are the Burnt Creek, Badger Creek Uplands, Lake McKenzie Basin, Long Lake, Apple Creek Uplands, Long Lake Basin, and Painted Woods Creek subdistricts.

The Missouri River Trench includes the floodplain, four recognizable outwash and alluvial terraces, and the dissected bedrock valley walls of the Missouri River. The Coteau Slope, the glaciated bedrock slope between the Missouri River Trench and the Missouri Coteau, is subject to active erosion by integrated streams draining into the Missouri River and has moderately thick to thin to non-existent drift. The Missouri Coteau, a high morainic belt of predominantly dead-ice moraine with associated stagnant ice-disintegration features, has non-integrated drainage and thick drift.

Pleistocene Wisconsin glaciation in Burleigh County consisted of the Napoleon, Long Lake, Burnstad, and Streeter ice advances. End moraine was deposited by the Long Lake and Streeter advances. Drift differentiation on a lithostratigraphic basis was not successful because the color, pebble lithology, and grain size of the drifts were nearly identical. Glacial morphostratigraphic units in Burleigh County are the Napoleon, Long Lake and Burnstad Drifts. A Pleistocene fossil molluscan fauna is represented by 30 specific and subspecific taxa of 19 genera. Molluscan shells in Burnstad Drift were radiocarbon dated at 9,990 and 10,100 years B.P.

The preglacial drainage in south-central North Dakota included the ancestral, northeastward trending, river systems of the Knife, Cannonball, Heart, and Grand Rivers. Two major glacial diversions of the Missouri River occurred in this area and captured the preglacial drainage, directing it southward. An extensive Wisconsin meltwater channel system existed in the Coteau Slope and was integrated into the Missouri River system.

The bedrock in Burleigh County consists of 8000 feet of Paleozoic, Mesozoic, and Cenozoic sedimentary rocks. The surface bedrock includes the Late Cretaceous Pierre, Fox Hills, and Hell

Creek Formations, and the Tertiary Paleocene Fort Union Group consisting of the Ludlow, Cannonball, and Tongue River Formations.

Major mineral resources in Burleigh County include sand and gravel, lignite, and water. No commercial oil production has been found.

INTRODUCTION

Scope and Purpose of Study

This is a general geological study of Burleigh County which comprises 1648 square miles in south-central North Dakota. The purpose is to provide a comprehensive investigation of the areal geology and the occurrence of ground water. The geological investigation is part of a cooperative ground water project involving three agencies: the North Dakota Geological Survey, the United States Geological Survey, and the North Dakota State Water Conservation Commission. This report presents the results of a comprehensive study of the surficial geology and a general study of the subsurface geology. The discussion of the surficial geology is based on surface mapping and test hole drilling, and includes a proposed physiographic classification, detailed descriptions of the exposed bedrock, profiles and cross-sections, the glacial geology, the drainage history, and the fossil molluscan fauna of Pleistocene sediments. The discussion of the subsurface geology includes a summary of petroleum exploratory drilling wells (tops of formations), cross-sections, and brief lithologic descriptions of the formations.

Methods of Study

The field work of the Burleigh County project began in September 1960 with the drilling of shallow test holes in the Long Lake area. The samples from 28 test holes were described by George E. Summers, Jr. and Jack Kume. In October 1960 approximately 100 square miles in southeastern Burleigh was mapped by Kume. During the field season of 1961 and May 1962 Dan E. Hansen mapped approximately 46 percent of Burleigh County in the central, northern, and eastern part. The remainder of the county was mapped by Kume during the field seasons of 1961 and 1962. During 1961 and 1962, 114 shallow test holes were completed. Most of the samples were described by Roger W. Schmid of the North Dakota State Water Conservation Commission, but some were described by Kume. In March 1963 four additional test holes were drilled in the Driscoll area, and the samples were described by Schmid. Electric logs were run in most of the test holes. Elevations were established for the test holes by the use of a United States Geological Survey matched set of altimeters.

The surficial geologic mapping was done on 1957 Burleigh County highway maps, scale 1:63,360, prepared by the North Dakota State Highway Department. Topographic maps including the Bismarck, Menoken, McKenzie and Driscoll 15 minute series; the Bismarck, Menoken SW, Mercer SW, Mercer SE, Horse Lake, and Florence Lake 7.5 minute series were used for mapping. Burleigh County (1952) aerial photo stereopairs, scale 1:63,360, obtained from the Aero Service Corporation were used to accurately place geologic contacts. The surficial mapping was done by driving along all the section line roads and trails, and lithologic determinations were recorded at each roadcut or exposure. Occasionally it was necessary to walk into less accessible areas within the section. In areas covered by shallow alluvium or wind-blown deposits, lithologic information was obtained by use of a hand auger, shovel, or a six foot post-hole auger mounted on a jeep. The color names used in the lithologic descriptions are those given in the Rock Color Chart (Goddard, and others, 1951).

The North Dakota State Water Conservation Commission provided a rotary rig for the drilling project. The United States Geological Survey provided a truck mounted auger capable of augering 100 feet for additional lithologic information.

Acknowledgments

The writers would like to express their appreciation to the various individuals and agencies who have contributed to this study. Dr. Wilson M. Laird, State Geologist, visited the writers in the field and made many helpful suggestions. He guided all phases of the fieldwork and manuscript preparation. Other members of the North Dakota Geological Survey also materially contributed to this study.

The friendly cooperation between the Federal and State agencies was sincerely appreciated. Edward Bradley, former District Geologist, U. S. Geological Survey, offered information, suggestions, and guidance. Phil G. Randich worked closely in the field with the writers, and aided in obtaining additional pertinent data. Milo W. Hoisveen, State Engineer, has shown continued interest in this study. The North Dakota State Water Conservation Commission was responsible for drilling the test holes. Roger W. Schmid provided lithologic descriptions of many of the test holes.

George E. Summers, Jr., geologist, was consulted during the initial phase of test drilling. Various individuals in Burleigh County have shown interest in this study, and landowners were cooperative in providing data of privately drilled test holes and access to their property for conducting investigations.

Previous Work

REGIONAL STUDIES

In 1883 Chamberlin presented a reconnaissance map of the Missouri Coteau in "Terminal Moraines of the Second Glacial Epoch." Todd (1896) described in detail the moraines of the Missouri Coteau. In Burleigh County, Todd mapped "the first, outer, or Altamont Moraine" and named the "Long Lake Loop". He discussed the preglacial drainage and thought that the Cannonball and Heart Rivers probably once flowed through Long Lake valley. Leonard (1916) described the "pre-Wisconsin drift" of North Dakota. He placed the western boundary of the Wisconsin drift at the front of the "Altamont Moraine." Townsend and Jenke (1951) named the "Max Moraine" for a portion of the vast area that was previously referred to as the "Altamont Moraine." They described the "Max Moraine" as extending "from the vicinity of Bismarck" northwestward for 800 miles. Colton and Lemke (1957) prepared a glacial map of North Dakota. Lemke and Colton (1958) presented a summary of the Pleistocene geology of North Dakota. In 1963, Colton, Lemke, and Lindvall published a preliminary glacial map of North Dakota. Their report and maps are an excellent source of information concerning the glacial deposits of North Dakota.

LOCAL STUDIES

Leonard (1912a, 1912b) mapped and described in detail the geology of the Bismarck quadrangle which included the southwestern part of Burleigh County, and parts of Morton, Emmons, and Oliver Counties. To the west, Laird and Mitchell (1942) described the geology of the southern part of Morton County. On the south, Fisher (1952) mapped and described the geology of Emmons County.

Hall (1958, unpublished Masters thesis) mapped the Cannonball Formation in south-central North Dakota which included the southwestern part of Burleigh County. Holland and Cvancara (1958) described fossil crabs from the Cannonball Formation of southern Burleigh and Morton Counties.

East of Burleigh County, Rau, Bakken, Chmelik, and Williams (1962) mapped and described the glacial geology of Kidder County. To the southeast, Clayton (1962) and Bonneville (1961, unpublished Masters thesis) mapped and described the glacial geology of Logan and McIntosh Counties. On the north, Sherrod and Gustavson (1963, 1964, unpublished Masters theses) have mapped and described the glacial geology of Sheridan County. East of Kidder County, Winters (1963) has described the geology of Stutsman County.

Summaries including lithologic descriptions of Burleigh County petroleum exploration drilling cuttings have been published (Caldwell, 1953a, 1953b, 1954; Smith, 1954; George, 1957; Eisenhard, 1958; Mendoza, 1959).

GEOGRAPHY

Location and Extent of Area

Burleigh County comprises 1648 square miles in Townships 137-144 North and Ranges 75-81 West in south-central North Dakota (fig. 1). The county is bordered on the south by Emmons County, on the east by Kidder County, on the north by Sheridan and McLean Counties, and on the west by Oliver and Morton Counties. The Missouri River forms most of the western county boundary.

Climate

Burleigh County is situated near the western boundary of the dry subhumid climate and the eastern boundary of the semiarid climate. The area is characterized by a wide temperature range, scanty rainfall, and rigorous winters. The prevailing wind direction is from the northwest. The coldest temperature recorded was -45°F and the warmest temperature was 114°F. The average temperature is 9.4°F in January and 70.9°F in July. The growing season averages 140 days. Annual precipitation is 15.34 inches of which over two-thirds falls between May and September. The average date for the first killing frost is September 27 and that for the last killing frost is May 10. These statistics are from records kept from 1900-1940 by the U. S. Department of Agriculture (1941). Trewartha (1954) has placed Burleigh County in the Humid Microthermal Continental Climate, Cool Summers or the "spring wheat" type of climate.

Culture

POPULATION

In 1960 Burleigh County had a population of 34,016 or about 21 people per square mile. Bismarck, the State Capitol and County Seat, with a population of 27,670, had 81.3 percent of the county population. The populations of the towns were as follows: Wilton (105 in Burleigh, 634 in McLean), Wing (303) and Regan (104) (U. S. Bureau of Census, 1960). Other unincorporated communities include Driscoll, Moffit, Sterling, Menoken, McKenzie, Arena, and Baldwin.

TRANSPORTATION

Burleigh County is served by the Northern Pacific Railroad which crosses the county in an east-west direction and by the Minneapolis, St. Paul, and Sault Ste. Marie Railroad which crosses in a southeast-northwest direction. The Northern Pacific has a main line from Driscoll to Bismarck and a branch line from Arena to Wilton.

Two Federal highways are paved across the county. U. S.

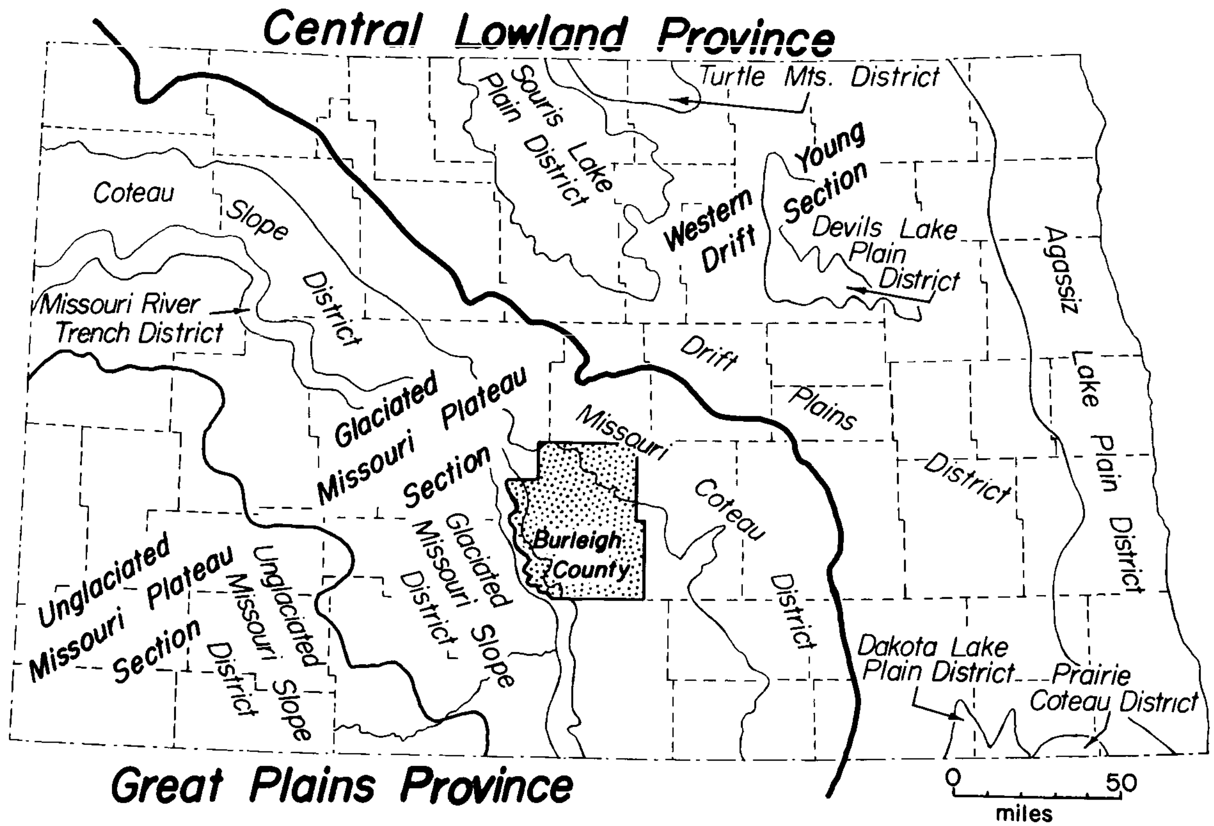

Figure 1. Index map showing location of Burleigh County and the physiographic subdivisions of North Dakota.

Highway 10 crosses in an east-west direction and U. S. Highway 83 crosses in a southeast-northwest direction. State Highway 41 along the northwest county border is paved. State Highway 14 from Sterling north across the county is an all weather partly bituminous and partly graveled road. Many all weather graveled roads and section line roads serve the county.

Airline service to Bismarck is provided by Northwest, Frontier and North Central Airlines.

INDUSTRY

Agriculture is the main industry. On the basis of the type of farming Kristjanson and Heltemes (1949) have placed Burleigh County in the South-Central Livestock-Grain Area. In 1950 forty-three percent of all farm land was worked by dryland methods. That same year 92 percent of the farms raised cattle. Gravel pits for construction and road metal are numerous. Lignite is mined in the Wilton area.

Soil

The soils of Burleigh County are classified in the Chestnut soil group, a dark brown soil of the cool and temperate, subhumid to semiarid grasslands (U. S. Department of Agriculture, 1941). The county can be divided into a southern and northwestern occurrence of dark brown soils separated by a northeastern, central western, and adjacent to Missouri River occurrence of the hilly and steep soils (Dept. of Soils, North Dakota State University and U. S. Soil Conservation Service, 1962, p. 73). The dark brown soils are loam and silt loam underlain by a light colored lime accumulation. These areas are used for grazing and the production of small grains, flax, corn, and forage. The hilly and steep soils on crests of hills and on steep slopes have a black or very dark brown surface layer but lack a subsoil, and the lime accumulation is very shallow. These areas are used mostly for grazing, but also for small grains and forage.

PHYSIOGRAPHIC UNITS AND LANDFORMS

Burleigh County, according to Fenneman's physiographic classification of the United States (1931, 1946 map), lies in the Interior Plains major division, the Great Plains province, and the Glaciated Missouri Plateau section. Fenneman (1931, p. 73-74) divided the Glaciated Missouri Plateau section at the Missouri River into two subdivisions and designated the morainic belt east of the river as the Missouri Coteau. Lemke and Colton (1958, fig. 1) subdivided the Glaciated Missouri Plateau section into four units, designating two of these units as the Missouri River Trench and the Coteau du Missouri. Clayton (1962, p. 14) has divided the Glaciated Missouri Plateau section into three districts: the Glaciated Missouri

Slope, Coteau Slope, and Missouri Coteau. In addition to these three districts a fourth district, the Missouri River Trench district (fig. 1 and table 1), is added in this report. These districts represent four distinct types of topography: (1) Missouri Coteau, the high morainic belt with non-integrated drainage; (2) Coteau Slope, the glaciated slope west of the Missouri Coteau, subject to active erosion with mostly integrated drainage; (3) Missouri River Trench, the floodplain, terraces, and dissected valley walls of the Missouri River; and (4) Glaciated Missouri Slope, the glaciated strip of dissected plateau west of the Missouri River subject to active erosion with integrated drainage.

Missouri River Trench District

The Missouri River Trench district in Burleigh County is characterized by a trench floor of variable width and valley walls steeply dissected in bedrock (fig. 2). The till is thin or non-existent; the alluvium and outwash are quite thick. Alluvial, outwash, and bedrock terraces are present, and various levels have been assigned to them (pl. 1 and fig. 2). The Missouri River flows southward diagonally across the regional strike of the bedrock in Burleigh County. North of Bismarck the gently curving stream meanders are inclosed by steep valley walls in a youthful valley. South of Bismarck the meanders broaden in a more mature valley which suggests that it was part of a preexisting drainage system.

TRENCH FLOOR

The trench floor of the Missouri River bordering Burleigh County varies in width from one mile (sec. 1 and 2, T. 141 N., R. 81 W.) to seven miles (immediately south of Bismarck). The constricted trench floor cuts across preglacial drainage divides (pl. 7). Twenty-one test holes in the trench floor show the average thickness of alluvium and outwash to be 100 to 115 feet thick, but immediately south of Bismarck it is up to 155 feet thick (pl. 5). The valley fill is composed mostly of sand and gravel, with minor silty and sandy clay. The only occurrence of till was reported in test hole 2057 which drilled through terrace 4 south of Bismarck. This early (?) Wisconsin till is underlain and overlain by outwash and alluvium. The till indicates early (?) Wisconsin glaciation over a preexisting valley partly filled with outwash.

Four terraces, numbered from the lowest to the highest, are recognized in the valley terrace complex (fig. 2). The highest terrace is the site of the State Penitentiary and is here designated the Penitentiary Terrace, or terrace 4. This outwash terrace is about 40 to 60 feet above the river level between the elevations of 1660 and 1680 feet. Terrace 4 probably represents a high fill and cut terrace. South of Bismarck terrace 4 lies over the buried channel of the ancestral Heart River. Here the depth to bedrock is 31 feet on the south, 170 feet in the central part, and 47 feet in the northern

TABLE 1.—Characteristics of the four districts of the Glaciated Missouri Plateau section in North Dakota.

	Glaciated Missouri Slope (Modified from Clayton, 1962)	Missouri River Trench	Coteau Slope (Modified from Clayton, 1962)	Missouri Coteau (Modified from Clayton, 1962)
Drainage	Integrated; Flows eastward	Integrated; Flows southward	Mostly integrated; Flows westward; Partly internal	Non-integrated; Numerous undrained depressions; Internal
Streams	Perennial, Intermittent, Ephemeral	Perennial, Intermittent, Ephemeral	Intermittent, Ephemeral	Nearly absent or very short segments; Ephemeral
Topography	Stream dissected bedrock	Floodplain, terraces Dissected valley wall	Stream dissected bedrock	Largely high glacial relief; Dead-ice moraine
Age of Drift	Early (?) Wisconsin	Early (?) Wisconsin	Mostly early (?) Wisconsin; Some late Wisconsin	Late Wisconsin
Drift Thickness	Non-existent or very thin	Thin to non-existent till, thick outwash and alluvium	Moderate, thin to non-existent	Thick

part of the terrace. The second highest, upon which the site of Fort Lincoln is located, is here designated the Fort Lincoln Terrace, or terrace 3. This outwash terrace is about 20 to 40 feet above the river level between the elevations of 1640 and 1660 feet. Fort Lincoln Terrace slopes gently toward the northwest and is marked by uneven cutting. A paired terrace, also designated terrace 3, on the west side of the river (fig. 2) has been cut into the

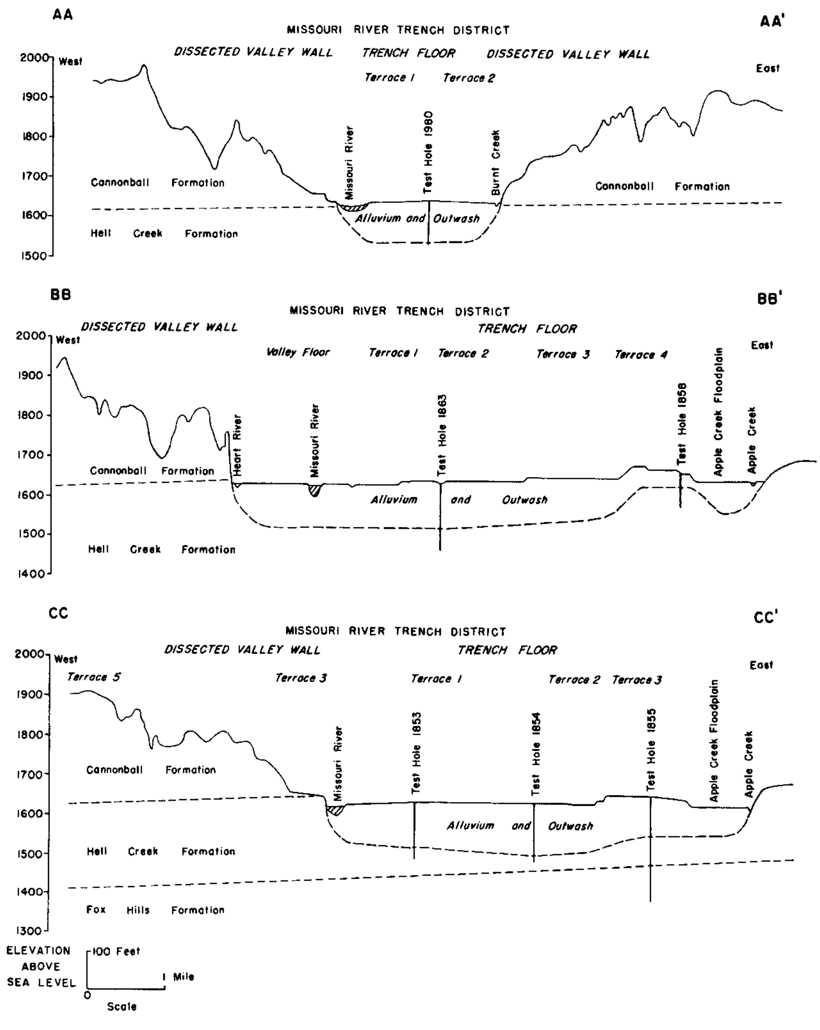

Figure 2. Profiles and geologic sections of the Missouri River Trench District.

Cannonball Formation. The two lowest are alluvial terraces at elevations between 1630 and 1640 feet and are here designated Wachter Terrace, or terrace 2, and Prison Farm Terrace, or terrace 1, for their development in the vicinity of the Wachter Farm and the Prison Farm properties. Wachter Terrace is quite featureless. The Prison Farm Terrace is a "bottom land" terrace marked by meander scars, bar deposits, and channel fillings. Separating terraces 1 and 2 is a low scarp which can easily be distinguished on aerial photos and topographic maps. Wood fragments collected by Rodger Schmid from an alluvial sand bed at a depth of 21 to 80 feet in test hole 1949 on terrace 1 have been radiocarbon dated at 210 $\pm$ 200 years B. P. (W-1432) in SW1/4 NW1/4 NE1/4 sec. 24, T. 137 N., R. 80 W. by the U. S. Geological Survey. Bedrock cut terraces 2 and 3, are covered by thin alluvium along the valley walls in west-central Burleigh County.

The floodplain alluvium adjacent to and within the river channel consists of channel and meander bars. These features, formed and modified by the present stream, consist chiefly of sand, silt, and clay.

Apple Creek floodplain, adjacent to and east of terraces 3 and 4, is included in the trench floor of the Missouri River Trench, because the bedrock trench filled with outwash and alluvium extends beneath Apple Creek to the east valley wall. However, the surface deposits of Apple Creek floodplain are composed of Recent alluvium. Apple Creek has been deflected southward by terrace 4 and has cut its floodplain below the level of terraces 3 and 4 (fig. 2).

DISSECTED VALLEY WALLS

The dissected valley walls of the Missouri River Trench are steep and rugged (fig. 2). In northwestern Burleigh County the walls rise to an elevation of 2200 feet, about 550 feet above the floodplain. Generally, the walls are about 450 feet higher than the floodplain. The bedrock valley walls are composed of the Hell Creek Formation in southwestern Burleigh, the Cannonball Formation in west-central Burleigh, and the Cannonball and Tongue River Formations in northwestern Burleigh. The Hell Creek and Cannonball Formations are easily eroded and form the lower slopes, whereas the basal Tongue River Formation contains a resistant limy sandstone and conglomerate bed which caps many of the buttes, hills, and ridges (section 10-62, Appendix A). The glacial drift on the dissected valley walls is generally thin or non-existent and consists chiefly of scattered boulders, except along the extreme northwestern border of the county where a thin sheet of till is draped over the bedrock. Several minor outwash deposits are also present. The till of the Napoleon Drift in some places extends to the floodplain, which indicates that the till covered area now included in the Missouri River Trench district was present prior to the early (?) Wisconsin Napoleon glaciation. It also suggests that the glacier probably extended further west, and at that time the Missouri River probably flowed through one of the diversion channels.

Active intermittent and ephemeral streams are rapidly eroding headward in the dissected valley wall. The top of the valley wall forms a sharp boundary between the Missouri River Trench district and the Burnt Creek subdistrict (fig. 2).

Along the dissected valley wall, above and adjacent to the floodplain, are bedrock terraces covered with a veneer of alluvium. These terraces, upstream extensions of terraces 2 and 3, are especially well-developed along the northwestern border of Burleigh County. The terrace surfaces slope gently toward the floodplain. The veneer consists of silt, probably partly reworked by wind, underlain by sand and gravel, and occasionally by till.

A prominent upland bench marks the upper boundary of the dissected valley walls at elevations of 1900 to 1940 feet, about 300 feet above the floodplain. It is here designated Custer Terrace, or terrace 5, because it is well-developed south of Mandan on Custer Flats.

Coteau Slope District

The Coteau Slope district in Burleigh County is the glaciated slope west of the Missouri Coteau district that is subject to active erosion by nearly completely integrated drainage. The streams flow westward to the Missouri River. The Coteau Slope district in Burleigh County is divided into seven proposed subdistricts (fig. 3) and their characteristics are summarized in table 2. These proposed physiographic subdivisions are given formal names for ease of discussion in this report.

BURNT CREEK SUBDISTRICT

Burnt Creek subdistrict coincides with the drainage basin of Burnt Creek and lies entirely within Burleigh County. This subdistrict is characterized by steeply dissected valley walls and uplands which, in part, contain a thin sheet of drift over bedrock. The drainage is completely integrated with intermittent and ephemeral streams flowing southward to the Missouri River.

Dissected valley walls and uplands. — The southern half of Burnt Creek subdistrict is highly dissected and the valley walls rise to an elevation of 2000 feet, about 300 feet above the Burnt Creek floodplain. The uplands rise to an elevation of 2160 feet at Keever Butte. Other prominent buttes in this subdistrict are Burnt, Ball, and Coal Buttes (pl. 1). The Tongue River Formation caps most of the buttes, hills, and ridges, and the Cannonball Formation forms most of the slopes and valley walls. Glacial drift in this area is thin to non-existent and consists mainly of scattered boulders and scattered patches of till. This valley was in existence at the time of early (?) Wisconsin glaciation as shown by patches of till in some places on the valley sides as well as on the uplands. Generally postglacial stream erosion has greatly modified the land surface throughout the area.

The alluvial sand and gravel in Burnt Creek valley is nine feet thick in test hole 1982 and fourteen feet thick in test hole 2004.

Moraine. — Moraines are landforms composed of accumulations of drift, chiefly till, deposited directly from glacial ice and having glacial constructional relief. Moraines have been classified into three major types: end moraine, dead-ice moraine, and ground moraine. In this study two additional minor types of moraines have been recognized: subdued-end moraine and sheet moraine.

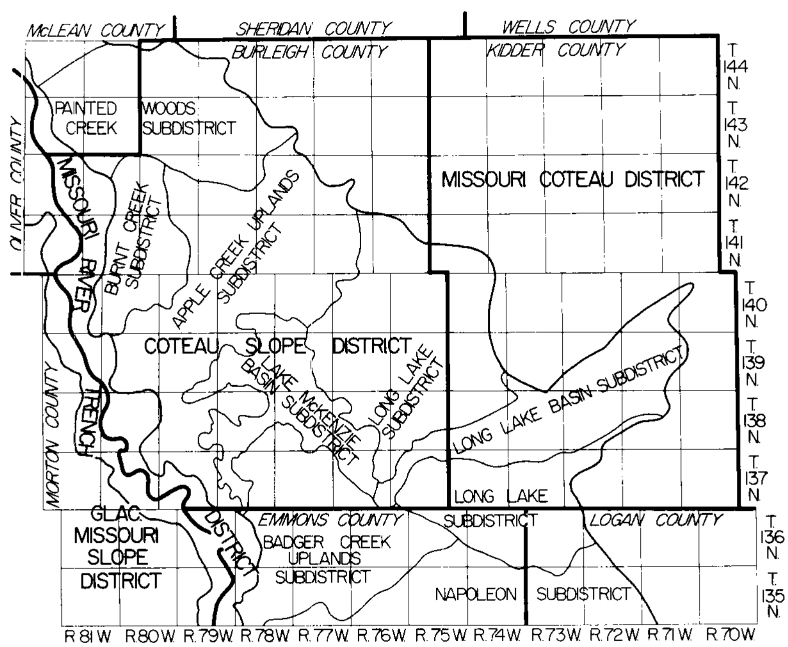

Figure 3. Map of the physiographic subdivisions of the Coteau Slopes district in Burleigh and Kidder Counties.

TABLE 2. – Characteristics of the seven subdistricts of the Coteau Slope district in Burleigh County.

	Painted Woods Creek Subdistrict	Burnt Creek Subdistrict	Apple Creek Uplands Subdistrict	Lake McKenzie Basin Subdistrict	Badger Creek Uplands Subdistrict	Long Lake Subdistrict	Long Lake Basin Subdistrict
Drainage	Partly integrated to non-integrated	Completely integrated	Almost completely integrated	Internal and partly integrated	Completely integrated	Non-integrated to partly integrated	Internal and partly integrated
Streams	Intermittent and Ephemeral	Intermittent and Ephemeral	Intermittent and Ephemeral	Ephemeral	Ephemeral	Ephemeral	Ephemeral
Undrained Depressions	Common to abundant	None	Few	Common	None	Very abundant	Common to abundant
Dominant Topography	Dead-ice moraine Sheet moraine Ground moraine	Stream eroded bedrock Extensive sheet moraine	Stream eroded bedrock Extensive sheet moraine Sand dunes	Lake plain Outwash plain Sand dunes	Stream eroded bedrock Minor sheet moraine	End moraine Ground moraine	Outwash plain Lake plain Sand dunes
Age of Surface Drift	Mostly late (?) Wisconsin	Early (?) Wisconsin	Mostly early (?) Wisconsin	Early (?) to late Wisconsin	Early (?) Wisconsin	Late Wisconsin	Late Wisconsin
Drift Thickness	25 to 80 feet	Absent to less than 40 feet	Absent to less than 50 feet	150 to 230 feet	Absent to less than 25 feet	50 to 175 feet	150 to 350 feet (Kidder County)

Sheet moraine. — The northern half of Burnt Creek subdistrict has a thin discontinuous layer of drift, chiefly composed of till, which is draped over stream-eroded bedrock topography. In this report the term sheet moraine is proposed to refer to this accumulation of drift. Sheet moraine is a landform composed of mappable, blanket-like, thin accumulations of drift deposited directly from glacial ice and having low glacial constructional relief. The general lack of kettles is an integral part of its recognition. In places this thin drift resembles ground moraine, but due to its thin nature, and since it reflects the topography of the underlying bedrock, it is not properly ground moraine (Flint, 1957, p. 131). In this report the term drift sheet refers to the entire drift accumulation related to a significant glacial advance. A drift sheet includes the outwash plain, end moraine, dead-ice moraine, ground moraine, and sheet moraine (fig. 4).

Sheet moraine in Burleigh County is generally found in areas of moderate to high relief reflecting the topography of the underlying bedrock. The sheet moraine in the Burnt Creek subdistrict is from 5 to 20 feet thick, overlying a stream-eroded topography which has 80 to 100 feet of relief per square mile and more in areas where the drainage is well-developed.

Meltwater channel. — Burnt Creek valley was a glacial meltwater channel (pl. 8) during the Wisconsin glaciation. Meltwater flowed southward to the Missouri River and deposited outwash in the channel.

BADGER CREEK UPLANDS SUBDISTRICT

Badger Creek Uplands subdistrict lies within Emmons and Burleigh Counties. In Burleigh County the subdistrict includes the bedrock upland area south of Lake McKenzie Basin subdistrict. In Emmons County this subdistrict includes the steeply dissected drainage basin of the ephemeral Badger Creek. In Burleigh County an upland bedrock ridge marks the north drainage divide of Badger Creek. North of this divide the land slopes toward Lake

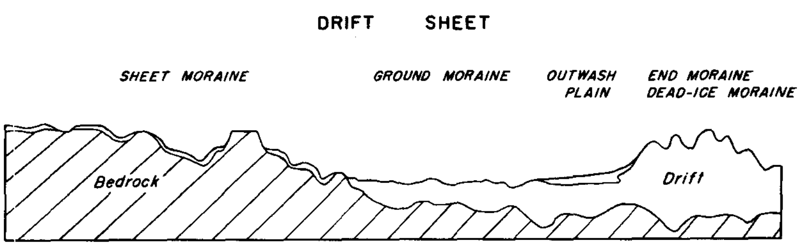

Figure 4. Diagrammatic profile and cross-section of a drift sheet.

McKenzie Basin. The drainage in this subdistrict is complete integrated.

Stream-eroded bedrock topography. — Most of the subdistrict has a stream-eroded bedrock topography. A few scattered patches of till and common boulder erratics give evidence that the area has been glaciated, but the surface shows only slight glacial modification. The highest uplands exceed 2200 feet in elevation, about 500 feet above McKenzie lake plain and Badger Creek. The Cannonball Formation caps most of the highest hills and ridges, whereas the Hell Creek Formation forms the steep slopes.

Four test holes were drilled to bedrock in this subdistrict. Test holes 1830 and 1868 encountered 19 and 20 feet of till respectively, and test holes 1936 and 2047 encountered 7 and 5 feet of clay respectively.

Meltwater channel. — Badger Creek valley is a deep channel of the ancestral Cannonball River system, which was cut into the Cretaceous Pierre and Fox Hills Formations. It was a significant meltwater channel during Wisconsin time (pl. 8) when the valley was partly filled with outwash and alluvium. South of Long Lake 179 feet of fill was found in test hole 1938 in Badger Creek valley.

Dune sand. — Eolian sand deposits characterized by dunes with numerous blowouts are present at three localities in this subdistrict. The largest dune area, part of which is in Lake McKenzie Basin subdistrict, covers about 14 square miles.

Individual dunes are usually low, but some attain 21 feet in height, and they are aligned in a northwesterly direction, paralleling the prevailing winds. The dunes are grass-covered and fairly stable except in a few blowout areas where the wind is actively removing the sand. The dunes are composed of a brown, fine-grained sand, mostly quartz, derived from glacial lake sediments and from local bedrock, especially the Cannonball Formation.

LAKE McKENZIE BASIN SUBDISTRICT

Lake McKenzie Basin lies entirely within Burleigh County, and it contains an extensive lake plain, a dune sand area, and an outwash plain. The basin is surrounded by the hills of the Long Lake moraine and the bedrock uplands of Badger Creek and Apple Creek subdistricts. The lake plain is in an extensive valley cut into the Fox Hills and Hell Creek Formations. Underlying the lake plain are buried channels of the ancestral Heart River (pl. 7) filled with lake sediments and outwash. Glacial Lake McKenzie was a proglacial and ice marginal lake during Wisconsin time. The present drainage in this subdistrict is internal and partly integrated.

Lake plain. — The gently undulating lake plain contains extensive swamps, the largest of which is McKenzie Slough. Long Lake is a permanent lake at the southeast boundary of the lake plain. The swamp and lake areas serve as catchment basins for the internal and partly integrated drainage. Apple, Random, and Long Lake Creeks are among the several streams in the subdistrict. The lake plain ranges from 1700 to 1730 feet (fig. 5) in elevation and slopes gently upward toward the outwash plain in the northern part of the subdistrict. The lake plain is 500 feet below the Badger Creek Uplands, 250 feet below the Long Lake end moraine, and 400 feet below Apple Creek Uplands. The southwestern part of the basin is confined to the narrow valley of Glencoe Channel where several knobs of bedrock protrude through the lake plain.

Undrained depressions or potholes are common in the lake

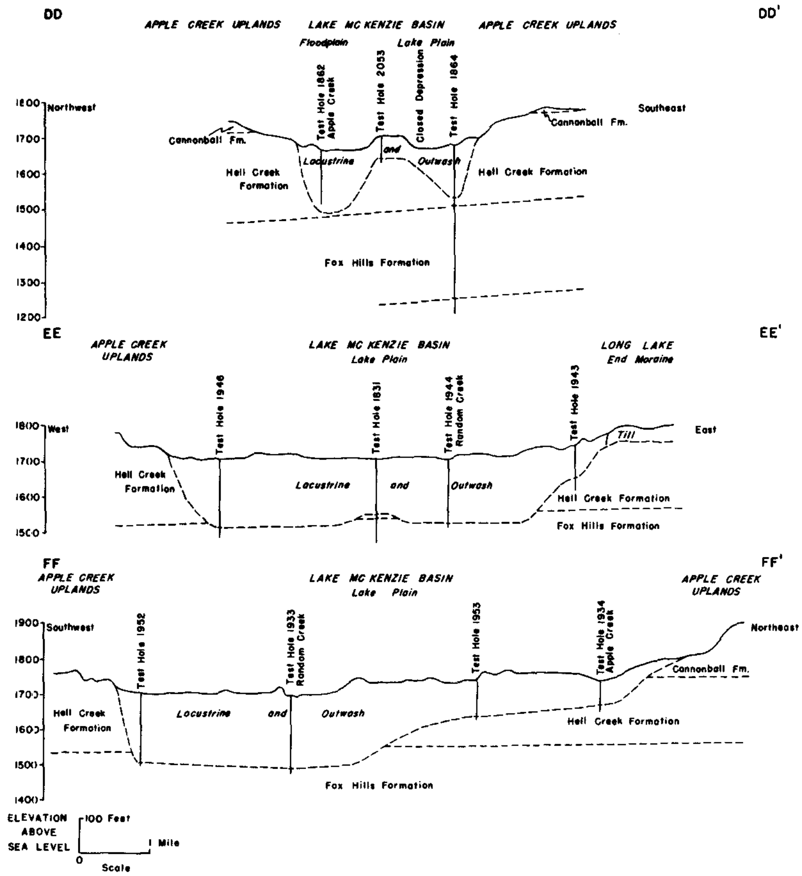

Figure 5. Profiles and geologic sections of the Lake McKenzie Basin.

plain especially in the Menoken and McKenzie area. The depressions are frequently 20 to 30 feet deep and are variable in extent. One of the larger depressions, in sec. 31, T. 139 N., R. 78 W., covers about a half a section. Test hole 1864, in this depression encountered 145 feet of lacustrine clay and silt, and two feet of gravel above the bedrock (fig. 5, section DD-DD[1]). The walls of the depressions are frequently very steep, as is shown in the depression immediately west of Menoken. Steep walled depressions would be anomalous in a lake plain unless they were formed as kettle holes. The kettles probably formed from individual blocks of ice that had rafted from the ice front or stagnant ice from a previous glacial advance. The blocks of ice were buried by lake sediments. When these blocks melted, steep walled depressions were formed. The present depressions usually contain some water in the spring and during wet years, but they are often dry during the summer and fall. Several permanent lakes occur in shallow depressions in the McKenzie Slough area. During times of abundant precipitation the overflow drains through Random Creek into Apple Creek. Apple Creek has incised its floodplain from 10 to 40 feet into the lake plain. Most of the Apple Creek floodplain deposits are probably Recent alluvium.

Dune sand. — The southwestern part of the subdistrict is characterized by sand dunes. The area is hummocky with low rounded, elongated hills of sand. The dunes are aligned in a northwest-southeast direction parallel to the prevailing winds. Blowouts are common in areas not covered by vegetation. The dune sand is underlain mostly by lake sediments, but along the southern border of the area, it is underlain by bedrock.

Outwash plain. — The northern and eastern part of the subdistrict is an outwash plain which has about 30 feet of local relief. The thin outwash sand and gravel is underlain by a thick sequence of clay and sand. Test hole 1953 encountered three feet of surficial sand and gravel underlain by 101 feet of clay and sand over bedrock. Test hole 2016, to the east, encountered clay and gravel over till. This outwash plain probably formed partly from material carried in by Long Lake glacial meltwater. However, most of the outwash was carried in by Burnstad and Streeter meltwater through Apple Creek Channel. Burnstad and Streeter meltwater flowing by way of Random Creek Channel through a breach in the Long Lake end moraine, deposited coarse material in Lake McKenzie forming an outwash plain. Test holes 1942, 1943, and 2028 indicate that a buried valley underlies this outwash and extends beneath the Long Lake moraine.

The outwash plain slopes gently toward the lake plain. The elevation of the outwash plain ranges from 1730 feet at the lake plain boundary to 1780 feet at the end moraine boundary.

Sheet moraine. — A thin accumulation of till on lake sediments and outwash occurs in the western part of Lake McKenzie Basin adjacent to Apple Creek. An auger hole (center SW1/4, sec. 3, T. 138 N., R. 79 W.) encountered 30 feet of early (?) Wisconsin till underlain by 70 feet of clay and sand. While this till was being deposited, the ice dammed this outlet to Glacial Lake McKenzie, forcing meltwater to flow through Glencoe and Badger Creek Channels.

Bedrock valley. — The large valley cut into bedrock in Lake McKenzie Basin is part of the ancestral Heart River system. Various segments of this system in the Lake McKenzie Basin are parts of the Glencoe Channel, Random Creek Channel, Apple Creek Channel, and Heart River Channel (pl. 3 and 7). The altitude of the bedrock valley ranges from about 1400 to 1650 feet, but the floor is commonly at 1500 to 1550 feet. Lake sediments over bedrock highs with 100 to 150 feet of relief above the valley floor are shown by test holes 1945, 1954 and 2054. In the Glencoe Channel, boulder covered bedrock knolls crop out of the lake plain.

Forty-six test holes were drilled in the basin. Thickness of the lake sediments and outwash material (pl. 5) is commonly 150 to 200 feet, but it ranges from about 60 to 230 feet (fig. 5). The maximum fill was encountered in test hole 1940. The basin fill is composed mostly of clay, silty and partly sandy, with variable amounts of sand and gravel. The buried gravel is generally confined to narrow elongate accumulations, or gravel trains, coinciding with the deeper bedrock valleys of the basin. A significant buried gravel train in the area southeast of McKenzie to a mile beyond test hole 1939 (pl. 4, section I-I[1]), is joined from the northeast by a buried gravel train beneath Random Creek. The thickness of these two gravel trains amounts to 23 feet in test hole 1939 and 51 feet in test hole 2023. Buried gravel trains are also present in the other parts of the Heart River Channel especially northwest of McKenzie and in Apple Creek valley. Glencoe Channel also contains significant amounts of buried gravel and an abundance of sand.

Buried till in the basin has been reported in test holes 1831, 1939, 2010, 2016, 2031, 2032, 2037, 2053, and 2054. Test holes 2016 and 2032 are adjacent to the Long Lake end moraine and the till is probably part of the same drift. The till in test holes 1831 and 1939 has been reported as questionable by the well site geologist. These two occurrences of till near the center of the basin may be remnants of a till sheet over a partly filled basin. Such may be the case in hole 2031 where the till is overlain by 134 feet of valley fill. The remaining four test holes containing till are in the Menoken area. The tills suggest glacial activity in the basin while it was being filled. Nearly all of the till was buried, but test hole 2054 encountered till on a bedrock drainage divide bordering Apple Creek Channel.

The valley walls are cut into the Cretaceous Hell Creek Formation. The valley floor is also the Hell Creek Formation, except in the deepest parts, where it is the Cretaceous Fox Hills Formation (fig. 5).

LONG LAKE SUBDISTRICT

The Long Lake subdistrict lies within Burleigh, Logan, Emmons, and Kidder Counties. The two major drainages in this subdistrict are Long Lake Creek and Random Creek. Much minor drainage on the western morainal slope flows into McKenzie Slough and Apple Creek. In eastern Burleigh County the drainage is non-integrated in part, and probably could have been included in the Misouri Coteau district, but this area includes part of the Long Lake end moraine and therefore is placed in the Long Lake subdistrict. The predominant landform is end moraine, with elevations ranging from 1780 feet north of McKenzie to 2100 feet east of Apple Creek.

Glacial Landforms

End moraine. — Landforms composed of accumulations of drift, chiefly till, deposited directly from an active glacier along its margin and having glacial constructional relief are end moraines. Linear trends are an integral part of their recognition. End moraines in Burleigh County have moderate to high local relief.

Todd (1896, p. 15) named and described the Long Lake loop of the Altamont moraine. The Long Lake end moraine lies within eastern Burleigh County, northeastern Emmons County, northwestern Logan County, and southwestern Kidder County.

In this study three loops of the Long Lake end moraine in eastern Burleigh County are recognized: the south, middle, and north loops. The drift of all three was deposited on bedrock highs. The south loop, breached by Long Lake, is characterized by an arcuate linear ridgelike accumulation of till. Slopes are steep with knobs and kettles. The local relief is about 40 to 60 feet with a maxmium of 100 feet. Boulders are quite numerous on the surface. The Cretaceous Fox Hills Formation is exposed in the south loop where it is breached by Long Lake. A prominent interlobate area that exists between the south and middle loops (fig. 6) is characterized by high local relief, prominent northeast-southwest linear ridges, and abundant kettles. The town of Sterling is built on the middle loop which is a rather wide, overall linear moraine rather than a ridged moraine. Boulders are fairly numerous on the surface of this gently sloping moraine on which the local relief is about 30 to 40 feet. The western slope has well-developed drainage. In contrast to the south loop, the middle loop has fewer kettles, moderate slopes, and a subdued topography, except for the southern part of the middle loop, where low till ridges resemble those of the south loop. The north loop is characterized by steep slopes and hummocky drift with numerous boulders on a southeast trending bedrock ridge. It is wide, has a few minor ridges, and contains local relief of 40 to 60 feet with a maximum of 100 feet. The western slope is well-drained, but the crest and inner parts have interior drainage. On the proximal side, the north loop grades into subdued end moraine. The north loop is overlapped at its northern boundary by dead-ice moraine and collapsed outwash topography. This overlap, acording to Clayton (1962, p. 30-31), represents a significant glacial readvance; however, it could also be a minor readvance or adjustment of the Long Lake icesheet. This correlation will be discussed in a later section with the Long Lake and Burnstad Drifts.

Ground moraine. — Landforms composed of accumulations of drift, chiefly of till, deposited directly from an active glacier behind its margin and having glacial constructional relief are ground moraines. Relative lower relief is an integral part of their recognition. Ground moraines in Burleigh County have low relief, and they may contain minor linear elements.

The Long Lake ground moraine lies within eastern Burleigh

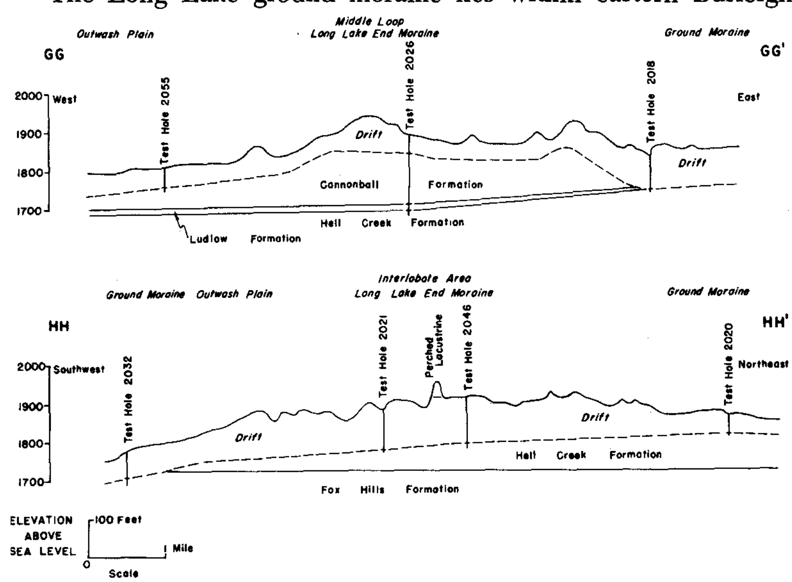

Figure 6. Profiles and geologic sections of the middle loop and the interlobate area between the middle and south loop of Long Lake end moraine.

County and western Kidder County on the proximal side of the end moraine loops. A narrow strip of ground moraine fringes Long Lake and is transitional with the south loop. Here the relief is low to moderate except for an occasional area of higher relief due to the underlying bedrock topography. Cretaceous Fox Hills Formation outcrops are surrounded by this ground moraine in Kidder County. Ground moraine on the proximal side of the middle loop is a till plain with about 5 to 20 feet of relief in the vicinity of the town of Driscoll. A few large lakes and sloughs are present, and surface boulders are fairly numerous. A small area of ground moraine occurs on the proximal side of the north loop. It is nearly flat with about five feet of relief. Because this ground moraine has no integrated drainage it is included in the Missouri Coteau district.

Collapsed outwash topography. — Landforms composed of hummocky accumulations of drift, chiefly glaciofluvial, with abundant kettles are defined as collapsed outwash topography. In Burleigh County collapsed outwash topography has moderate to high relief.

Collapsed outwash topography occurs on the distal side of the north loop of the Long Lake end moraine adjacent to the East Branch of Apple Creek. The relief ranges from low to high with a maximum of 50 feet. The outwash was deposited on disintegrating ice and collapsed when the ice melted.

A small area of collapsed outwash topography with local relief of 30 to 40 feet lies between the north and middle loops. The outwash surface is characterized by a series of random ridges and scattered erratic boulders.

Ice-contact lacustrine topography. — A perched or elevated landform composed of accumulations of drift, chiefly glaciolacustrine, deposited in an ice-walled lake is defined as ice-contact lacustrine topography. The deposits are usually stratified and have steep ice-contact faces.

Small ice-contact lacustrine deposits occur in the interlobate area between the south and middle loops, capping three prominent till highs whose local relief ranges from 80 to 100 feet above the surrounding end moraine (fig. 6). The lake sediments are about 35 feet thick and consist of alternating dusky yellow and light olive-gray laminated silts and clays. Test hole 2025 penetrated 153 feet of till beneath the perched lake sediments. The lake sediments are horizontally bedded, but the landforms are rounded, probably due to slumping of the steep ice-contact edges.

In another small area of ice-contact lacustrine deposits in the north loop, the lake sediments have about 20 to 25 feet of relief and slope into a large kettle.

Linear distintegration ridges. — Linear, narrow, boulder covered ridges composed of unsorted outwash and till are superimposed on the Long Lake end moraine. These ridges are similar to eskers or crevasse fillings, but differ from them in composition as they are usually not composed of washed and bedded drift. Linear disintegration ridges were formed during the disintegration of stagnant glacial ice. Disintegration ridges are more numerous and of greater variety in the dead-ice moraine of northern Burleigh County, so a detailed description is presented with the discussion of the Missouri Coteau district.

In the middle loop there are three occurrences of linear disintegration ridges: (1) A till ridge extending from sec. 18, T. 140 N., R. 75 W., into sec. 24, T. 140 N., R. 76 W. The relatively straight boulder covered ridge is almost two miles in length with local relief of 15 to 20 feet and a maximum of 30 feet; (2) A ridge about half a mile long in secs. 5, 7, and 8, T. 140 N., R. 75 W., composed of washed drift with relief of 5 to 15 feet; and (3) An east-west boulder covered ridge in secs. 31 and 32, T. 140 N., R. 75 W. and sec. 36, T. 140 N., R 76 W. This prominent narrow, linear ridge has relief of up to 30 feet and is composed of till and washed drift. In the north loop are two areas of linear disintegration ridges: (1) Several short ridges in the frontal part of the north loop composed of till and unsorted gravel, with up to 10 feet of relief; and (2) A narrow till ridge about two miles long in secs. 28 and 29, T. 142 N., R. 75 W. This ridge lies in an east-west direction about three-fourths of a mile south of an area of collapsed outwash topography. Relief of the ridge is 5 to 20 feet.

Kames. — Kames are prominent hills composed of outwash and till deposited in contact with, or within glacial ice.

In the middle loop is a boulder covered kame in sec. 17, T. 141 N., R. 75 W. with relief of about 40 to 50 feet. A rather low kame in the middle loop about a mile west of Sterling has been breached by roadcuts on U. S. Highway 10. This kame is composed of poorly sorted outwash and probably had less than 30 feet of relief. A low kamelike mound about a quarter of a mile to the east of this kame has about 10 to 15 feet of relief. Another kamelike mound is in sec. 15, T. 139 N., R. 76 W.

In the interlobate area between the middle and south loop a prominent kame in secs. 18 and 19, T. 138 N., R. 75 W. has about 30 feet of relief.

Partly buried channels and kettle chains. — Prominent channel sags partly buried by drift, and channels marked by an alignment of numerous kettles are partly buried channels and kettle chains.

A partly buried channel in the middle loop and the adjacent ground moraine in secs. 1, 12, and 13, T. 140 N., R. 75 W., extends southeastward into Kidder County. Test holes penetrated as much as 168 feet of till and gravel in the buried channel. In Burleigh County this channel has about 35 feet of relief in the ground moraine and 60 to 100 feet of relief in the end moraine. In Kidder County this channel is competely buried by ground moraine.

In the south loop a kettle chain in secs. 12, 13, and 14, T. 138 N., R. 75 W. extends southwestward from Kidder County into Burleigh County. The kettle chain has 40 to 60 feet of relief. The southern end of the kettle chain joins a valley that extends to Long Lake.

Proglacial Landforms

Outwash plains. – Gently undulating to nearly flat landforms of generally stratified accumulations of drift, chiefly glaciofluvial sediments, are outwash plains.

Outwash plains on the distal side of the three Long Lake end moraine loops are composed of sand and gravel. The outwash plains have low relief of about 5 to 10 feet, and they slope westward into the sediments of the Lake McKenzie Basin. Several irregular thin outwash deposits occur near the Long Lake breach of the south loop, surrounding Cretaceous Fox Hills Formation outcrops. Outwash merges into ground moraine on the distal side of the south loop and in the interlobate area. An extensive outwash plain on the distal side of the middle loop has been discussed in the section on Lake McKenzie Basin subdistrict. This slightly pitted outwash plain furnished the sand and silt that was wind deposited on the western edge of the middle loop.

Outwash valley floor. – A landform composed of accumulations of drift, chiefly stratified glaciofluvial sediments in a valley, is an outwash valley floor.

Outwash valley floor in a meltwater channel extends from the ground moraine area on the proximal side of the middle loop to Lake McKenzie Basin. It occurs in a shallow meltwater channel from Kidder County to the middle loop. The channel, now occupied by Random Creek, breaches the middle loop southeast of Sterling through a 60 foot cut. The fact that this channel is extremely shallow in the ground moraine, and that it breaches the end moraine, suggests that meltwater was probably flowing in a superglacial channel while the middle loop was being deposited.

Lake plain. – A lake plain lies in the Rice Lake area between the middle and north loops. Lacustrine clays and silts are exposed in road cuts along North Dakota Highway 14. The lake plain merges with collapsed outwash topography to the west and northwest. This general area was probably part of a pre-existing valley which was partly filled with lake and outwash deposits.

APPLE CREEK UPLANDS SUBDISTRICT

Apple Creek Uplands subdistrict is characterized by stream-eroded bedrock topography extensively covered by sheet moraine. The subdistrict nearly coincides with the drainage basin of Apple Creek which is completely integrated. An extensive sand dune area characterizes the southern part of this subdistrict.

Stream-eroded bedrock topography. – Much of the subdistrict contains a glacially modified, stream-eroded bedrock topography. Boulder erratics are common, and a thin layer of till covers much of the area. Bedrock crops out throughout the subdistrict, and many small areas were mapped as bedrock, because the till cover was thin or non-existent except for scattered erratic boulders.

The highest uplands are at an elevation of over 2200 feet, about 700 feet above the McKenzie lake plain. The local relief is commonly over 100 feet per square mile, but may reach several hundred feet in the butte areas. The Tongue River Formation caps most of the highest uplands in the northern part of the subdistrict with the Cannonball Formation forming the lower slopes. In the southern one-third of the subdistrict the Cannonball Formation caps the uplands and the Hell Creek Formation forms the lower slopes. Generally, postglacial stream erosion has been extensive.

Sheet moraine. – The northern two-thirds of the subdistrict has an extensive but discontinuous sheet moraine cover. Local relief on the sheet moraine area is commonly over 100 feet per square mile, but this is merely a reflection of the bedrock topography. The sheet moraine contains a few scattered kettles, and the drift is generally less than 10 feet thick.

Kames. – Kames, in groups of two or three, composed of till, sand, and gravel are numerous in the northeastern part of this subdistrict. Perhaps the most conspicuous kames are in secs. 10, 15, and 16, T. 141 N., R. 77 W. (fig. 7). Here, there are three groups of kames on sheet moraine behind a high bedrock ridge. The relief of the kames is approximately 50 to 75 feet. Boulders are common and the bedding, though not well-developed, is best seen in a gravel pit in sec. 10 (fig. 7). The next township to the east, T. 141 N., R. 76 W., has kames in secs. 7, 8, 17, and 18. The next township to the north, T. 142 N., R. 76 W., has kames in secs. 5 and 6. Here, the kames have 10 to 30 feet of local relief. Three adjoining kames with nearly flat bedding in sec. 24, T. 142 N., R. 77 W. have about 30 feet of relief. Two minor kames are in secs. 14 and 23, T. 141 N., R. 79 W.

Meltwater channels and outwash valley floor. – The streams of this subdistrict are ephemeral except for the intermittent Apple Creek. All of the major drainage valleys contain some outwash, and during glaciation most of these channels carried meltwater.

Figure 7. — Prominent kames in Apple Creek Uplands subdistrict (T. 144N., R. 77 W., Burleigh County). Upper picture: Kame complex in sec. 15. Lower two pictures: Gravel exposures in a kame in sec. 10. Note the bedding and boulders.

In the northeastern part of this subdistrict several upper branches of the East Branch of Apple Creek probably were significant meltwater channels (pl. 8). One of these upper branches, extending southward from the village of Wing, follows along the front of the Long Lake end moraine. This channel has made cuts from 40 to 125 feet deep, with an average depth of 100 feet. Test hole data indicate a valley fill thickness of about 57 feet. Another upper branch meltwater channel extends southeastward from Lake Canfield. This meltwater channel was superimposed on a high bedrock drainage divide and joined the meltwater channel from Wing. The relief of this channel ranges from about 30 feet in the northern part to about 150 feet where it passes through the high bedrock area. Commonly, it has about 120 feet of relief. Thirty feet of valley fill was encountered in one test hole. Apparently these two upper branch channels carried meltwater from the ablating Burnstad ice (pl. 8).

The valley occupied by West Branch of Apple Creek contains an outwash valley floor. The valley fill ranges from 4 to 20 feet thick in three test holes. Apparently this channel carried meltwater mostly from the ablating Napoleon ice.

Dune sand. – Eolian sand deposits are characterized by dunes and blowouts southeast of Bismarck in two separate areas in this subdistrict. South of Apple Creek the largest dune development in Burleigh County covers about 21 square miles. The dune area is in a broad upland valley between bedrock hills. The valley probably was a preglacial channel and a minor meltwater channel. As shown by two auger holes, in secs. 20 and 19, T. 138 N., R. 79 W., respectively, the sand ranged from 1 to 3 feet thick. However, a sand thickness of 5 to 15 feet has been observed in blowouts. The dunes are low, rounded and elongated mounds of sand oriented in a northwesterly direction. A dune area is also present along the Burleigh-Emmons County line.

LONG LAKE BASIN SUBDISTRICT

Long Lake Basin subdistrict lies mostly within Kidder County, but it extends into southeastern Burleigh County at Long Lake. In Kidder County this subdistrict is characterized by internal and partly integrated drainage. Topographically, it is a broad basin containing an extensive outwash and lake plain. Dune sand is present in two separate areas. Surrounding much of the basin is the high morainal belt of the Missouri Coteau which has nonintegrated drainage.

Outwash and lake plain. – The outwash and lake plain of this subdistrict is nearly flat, but it slopes gently toward the center of the basin. The elevation of the basin is about 1800 feet at the edge and about 1700 feet at the center. The surface deposits are mostly sand, but clay deposits are common. Several large aligned kettles, near the center of the basin, are in a chain that nearly marks the buried channel of the ancestral Cannonball River. Here, the valley fill ranges from 124 to 168 feet thick in Burleigh County and up to 300 feet thick in Kidder County. The fill is composed of sand, clay, till, and gravel. The bedrock valley of the ancestral Cannonball River is cut into the Cretaceous Pierre and Fox Hills Formations.

Dune sand. – Sand dunes occur in two areas in the Long Lake Basin subdistrict (Rau, and others, 1962). The largest dune area, six miles south of the town of Dawson, covers about 25 square miles, and the other covers about three square miles near the town of Tappen.

PAINTED WOODS CREEK SUBDISTRICT

Painted Woods Creek subdistrict lies within McLean and Burleigh Counties. The glacial topography of this subdistrict is transitional from thin drift covered bedrock on the south to dead-ice moraine in the northern part. The drainage basin of Painted Woods Creek is the site of a large drift covered bedrock valley. The predominant landform, dead-ice moraine, is due to drift accumulation by large-scale stagnation of continental glaciers. The valley is cut into the Tongue River Formation in the southern uplands and into the Cannonball Formation in the remainder of the subdistrict. Elevations in Painted Woods Creek subdistrict range from 1790 to 2100 feet.

Glacial Landforms

Dead-ice moraine. – Landforms composed chiefly of hummocky accumulations of drift, chiefy till, with 20 to 60 feet of relief extend from the Missouri Coteau district into the Painted Woods Creek subdistrict. These landforms, which are called dead-ice moraine, are deposited by stagnant glacial ice. A detailed discussion of dead-ice moraine is presented in the description of the Missouri Coteau district. The dead-ice moraine in this subdistrict contains numerous sloughs, is notable for surface boulders, and ranges from 25 to 80 feet thick. Elevations on the moraine range from 1790 to 2000 feet.

An elongate area mapped as dead-ice moraine north of Grass Lake may possibly be an end moraine without well-developed ridges. However, the bedrock is at shallow depths in this area, and the preglacial bedrock surface is reflected in the overlying dead-ice moraine.

Collapsed outwash topography. – Hummocky outwash borders the dead-ice moraine northwest of the town of Regan. The relief of this collapsed outwash ranges from 10 to 30 feet and it lies at elevations between 2020 and 2060 feet. The northern boundary between the outwash and the dead-ice moraine is marked by a narrow disintegration ridge composed of till and gravel. Collapsed outwash along the south valley wall of Painted Woods Creek in sec. 25, T. 144 N., R. 79 W., and sec. 30, T. 144 N., R. 80 W. merges into an outwash terrace which is probably stream-modified collapsed outwash. Elevations on the collapsed outwash range from 1840 to 1870 feet and the local relief is about 10 to 20 feet.

Linear disintegration ridges. — Several short gravel and sand ridges with 10 to 30 feet of relief are along the valley wall of Painted Woods Creek in T. 144 N., R. 79 W. In sec. 29, one ridge extends down on the valley floor. Scattered boulders are abundant on the ridges. Two ridges, one composed of gravel and the other of till, in the northern part of sec. 3 have from 5 to 15 feet of relief.

Sheet moraine. — The upland area south of the dead-ice moraine contains sheet moraine. The topography is gently rolling with from 10 to 100 feet of relief at elevations ranging between 2000 and 2200 feet. The Tongue River Formation crops out of the drift which ranges in thickness from a veneer to about 40 feet. Surface boulders on the drift are sporadically numerous, and here kettles are more abundant than in the sheet moraine south of this subdistrict.

Proglacial landforms

Meltwater channels and outwash valley floor. — Painted Woods Creek flows in a meltwater channel which ranges from about a quarter of a mile to two miles wide. The Cannonball Formation crops out in three places in the channel. Outwash on the valley floor composed of gravel, sand, and clay, ranges in thickness from 20 to 66 feet. Elevations in the channel range from 1790 feet at the Burleigh-McLean County line to 1850 feet three miles south of the Sheridan County line. Meltwater probably formed the channel during stagnation and ablation of the Burnstad ice, and much of the valley floor outwash probably was deposited during the ablation of the Streeter ice.

A shallow meltwater channel along the southern boundary of the dead-ice moraine is marked by sloughs. Valley outwash composed of sand and clay was deposited in the channel which was probably formed by meltwater during the ablation of Burnstad ice.

Nonglacial Landforms

Recent drainage. — Painted Woods Creek is an intermittent stream in a meltwater channel. Well-developed tributaries to Painted Woods Creek in the dead-ice moraine along the southern part of the drainage basin have incised the drift as much as 80 feet.

Missouri Coteau District

The Missouri Coteau district includes the northeastern part of Burleigh County and is characterized by extensive areas of dead-ice moraine and associated stagnant ice-disintegration features such as: collapsed outwash topography, disintegration trenches, disintegration ridges, abundant kettles containing lakes and sloughs, collapsed lacustrine topography, kames, and kame terraces. The predominant landform, dead-ice moraine, is due to drift accumulation by large-scale stagnation of continental glaciers. This landform is well-preserved in this district because the drainage is not integrated and postglacial erosion is insignificant.

The Missouri Coteau district contains the highest glacial constructional relief and thickest till in Burleigh County. The drift ranges from a feather edge near the bedrock outcrop areas to a maximum thickness of 165 feet, with an average thickness of about 60 feet. However, the topography along part of the western boundary of the Missouri Coteau district reflects the till-covered bedrock highs of the Fort Union Group. The Cannonball Formation crops out in several small exposures southwest and northwest of Wing (pl. 1). The Tongue River Formation crops out in an upland ridge northwest of Haystack Butte.

The Florence Lake loop of the Streeter end moraine is in the Missouri Coteau district along the Burleigh-Sheridan County line. Dead-ice moraine borders both sides of the Streeter end moraine.

Glacial Landforms

Dead-ice moraine. — Landforms composed of hummocky accumulations of drift, chiefly till, deposited directly by stagnant glacial ice and having glacial constructional relief are dead-ice moraines. Generally dead-ice moraine lacks linear trends, contains abundant knobs and kettles, high constructional relief, and non-integrated drainage.

Dead-ice moraine in Burleigh County has high relief of 50 to 150 feet, and the maximum relief is due partly to underlying bedrock highs. The dead-ice moraine lacks linear trends, contains abundant kettles with small sloughs and lakes, and is composed chiefly of till with minor accumulations of outwash and lacustrine sediments. Surface boulders are abundant. The dead-ice moraine in Burleigh County occurs at elevations between 1900 and 2100 feet.

Associated with the dead-ice moraine are stagnant ice-disintegration features which will be discussed under separate headings. Gravenor and Kupsch (1959, p. 48-64) have classified these features in three groups: (1) controlled disintegration features which show the influence of the previous active ice; (2) uncontrolled disintegration features which do not reveal the influence of former ice flow; and (3) disintegration features which were superimposed on active ice features. Using their classification the controlled disintegration features in this district include linear disintegration ridges and kettle chains. The uncontrolled disintegration features include collapsed outwash topography, closed disintegration ridges, collapsed lacustrine topography, kames, and kame terraces. Disintegration trenches are both controlled and uncontrolled disintegration features (Clayton, 1964, oral communication). The linear disintegration ridges on the end moraine in Long Lake subdistrict, exemplify superimposed disintegration features.

The origin of morainal topography in the Missouri Coteau district was suggested by Townsend and Jenke (1951, p. 857), who thought that it "may have been deposited largely by ablation." They also suggested that the moraine "may be a special type more nearly related in extent and mode of deposition to ground moraine than to end moraine." The terminology, origin, and usage of dead-ice moraine has been discussed by various workers (Christiansen, 1956; Lemke and Colton, 1958; Gravenor and Kupsch, 1959; Rau, and others, 1962; Clayton, 1962; and Winters, 1963). For a detailed background on dead-ice moraine these works should be consulted as only a brief discussion is presented here.

The dead-ice moraine in Burleigh County probably originated in much the same manner as that in Logan and McIntosh Counties. Clayton (1962, p. 34-38) discussed this origin and part of his interpretation was: (1) the high relief probably originated from "letting-down of superglacial till from stagnant ice"; (2) most of the superglacial drift probably originated from marginal imbricate thrusting of thin ice; (3) the ice was covered by an insulating blanket of drift which resulted in slow melting and a wide band of stagnant ice; and (4) dead-ice moraine is the result of large-scale glacial stagnation.

The dead-ice moraine in Burleigh County reaches a maximum thickness of 165 feet which is much thinner than the maximum of 500 feet in Logan and McIntosh Counties. The maximum relief is similiar being about 100 feet in both areas.

Collapsed outwash topography. — Landforms composed chiefly of hummocky accumulations of drift, chiefly glaciofluvial sediments with abundant kettles, are included in collapsed outwash topography. In Burleigh County, collapsed outwash topography has moderate to high relief, similar to that of dead-ice moraine. Ice-disintegration ridges are commonly associated with collapsed outwash.

In Burleigh County the collapsed outwash topography in T. 142 N., R. 75 W. is a westward continuation of an extensive outwash area in Kidder County which was deposited by the Burnstad advance (Clayton, 1962, p. 31 and 63). Elevations on the outwash range between 1840 and 1900 feet, and the local relief is about 10 to 50 feet. Kettles and ice-contact features are abundant. A channel-like extension of collapsed outwash trends from Harriet Lake northwest to Wing.

North of Arena and Wing (pl. 1) are several minor areas of collapsed outwash topography in the dead-ice moraine. The outwash is thin with moderate relief and hummocky topography. To the north is a channel-like deposit of collapsed outwash composed of numerous boulder covered low ridges that coalesce to form an outwash sheet of moderate relief. The relief of the ridges is about 5 to 15 feet. Another area of boulder covered collapsed outwash to the northwest has low to moderate relief. Four miles north of Wing a relatively flat outwash surface is elevated 50 to 80 feet above the surrounding topography. It is similar to the ice-restricted lacustrine deposits of the "moraine plateaus" as described by Gravenor and Kupsch (1959, p. 51-52). West of Wing is an area of ice-marginal collapsed outwash with relief of 5 to 20 feet.

The largest area of collapsed outwash topography occurs on the distal side of the Streeter end moraine (pl. 1) and it is generally less than 30 feet thick. The collapsed outwash is thicker near Bunce Lake where 50 feet of gravel is exposed, and it is through this layer of outwash gravel that the lake is recharged. Kettle lakes are abundant in the outwash. The elevation of the outwash ranges from 1930 to 2000 feet, and the relief is moderate.

East of Painted Woods Creek (pl. 1) is a small area of collapsed outwash topography with relief of about 30 feet. To the east the outwash merges with dead-ice moraine.

Another minor area of collapsed outwash topography along the Burleigh-Sheridan County line, is at an elevation of 1950 feet with 15 to 25 feet of relief.

Disintegration trenches. — Clayton (1962, p. 42) first recognized and defined disintegration trenches as being "a trench or channel formed by the inversion of topography on disintegrating stagnant glacial ice and subsequent burial under outwash."

Disintegration trenches in northern Burleigh County are recognized on aerial photo stereopairs, but are difficult to identify in the field. The trenches are short and have a random pattern. These trenches, common in all of the areas of collapsed outwash topography, are best developed southwest of Salt Lake.

Linear disintegration ridges. — Narrow ridges of drift, composed chiefly of till, are common in the dead-ice moraine and collapsed outwash topography in the Missouri Coteau district. Gravenor and Kupsch (1959, p. 53-54) have defined linear disintegration ridges as straight or slightly arcuate, linear ridges resulting from controlled ice disintegration and composed chiefly of till which may contain pockets of stratified material. They (p. 49) define controlled ice disintegration as the process of ice separation along fractures in a stagnant glacier.

Disintegration ridges in Burleigh County are narrow, straight or arcuate, linear ridges, are generally less than 30 feet high, are less than a mile to several miles long, and are composed either of till, outwash, or a mixture of the two. Surface boulders are a common feature of these ridges.

Three disintegration ridges occur in the collapsed outwash topography in sec. 24, T. 142 N., R. 76 W. These till and gravel ridges are 5 to 15 feet high and less than a quarter of a mile long. Several other short disintegration ridges in and along a meltwater channel southwest of Wing are 5 to 10 feet high and are composed chiefly of gravel.

A series of short disintegration ridges in the dead-ice moraine northwest of Arena are as much as 30 feet high. These boulder covered ridges, aligned in a southeastward trend for about five miles, extend from dead-ice moraine to collapsed outwash topography. Two small kamelike mounds are associated with these ridges.

A disintegration ridge about 5 miles long marks the boundary between dead-ice moraine and the outwash plain on the distal side of the Streeter end moraine. The boulder covered ridge is up to 200 feet wide with 20 to 30 feet of relief.

Other disintegration ridges occur in the dead-ice moraine in secs. 27 and 28, T. 144 N., R. 77 W. and in sec. 3, T. 144 N., R. 79 W. These ridges are generally less than a mile long.

Closed disintegration ridges. – Circular, oval, or irregularly closed ridges of drift, composed chiefly of till, are common in the dead-ice moraine in the Missouri Coteau district. Gravenor and Kupsch (1959, p. 52-53) have defined closed disintegration ridges as circular, oval, or irregularly closed ridges of glacial material, chiefly till, resulting from uncontrolled ice disintegration. They (p. 49) define uncontrolled ice disintegration as the breaking up of an ice sheet equally in all directions into numerous small blocks.

Closed disintegration ridges occur throughout the dead-ice moraine of Burleigh County but less commonly than in many other areas of the Missouri Coteau district. In Burleigh County the ridges generally are 50 to 300 feet in diameter, less than 10 feet high, and are rudely circular in plan. The ridges are composed chiefly of till with pockets of washed drift. The more regular circular ridges surround an obvious central depression and some of the oval shaped ridges are breached at both ends. Closed disintegration ridges are difficult to observe in the field but are very noticeable on aerial photos.

Collapsed lacustrine topography. — Very small areas of collapsed lacustrine deposits occur along the rims of depressions and kettles in the dead-ice moraine. The depressions are usually 5 to 10 feet deep, and rarely attain a depth of 20 feet. The rimmed lacustrine deposits are slightly elevated above the depression and are composed of clay and silt which appears to grade into the surrounding till.

The collapsed lacustrine deposits are fossiliferous and collections have been made from a number of sites (see discussion of the fossil molluscan fauna of Pleistocene sediments). The branchiate molluscan fauna indicates that the enclosing sediments were deposited in permanent ponds, whereas the existing sloughs are ephemeral.

Kame terraces and kames. — A terracelike accumulation of ice-contact stratified drift, composed chiefly of glaciofluvial materials, deposited between glacial ice and an adjacent valley wall is a kame terrace.

A series of paired kame terraces occur about 30 feet above an east-west meltwater channel in secs. 23 and 24, T. 143 N., R. 76 W., adjacent to the Long Lake north loop boundary. The terraces are composed of two to six feet of sand and gravel, have about five feet of relief, and are partly covered by boulders. Streams have modified these terraces.

A kame with 25 feet of relief occurs in sec. 25, T. 144 N., R. 75 W. In this area of dead-ice moraine only a few recognizable kames are present. A kame occurs in sec. 36, T. 143 N., R. 77 W.

Kettle chains. — Northeast of Canfield Lake a kettle chain in a drift covered drainage channel breaches a bedrock ridge in secs. 10 and 16, T. 143 N., R. 77 W. The kettle chain is narrow and has up to 40 feet of relief. Another kettle chain along the Burleigh-Sheridan County line in secs. 1 and 2, T. 144 N., R. 79 W. is about half a mile wide, and has 30 to 40 feet of relief.

End moraine. — The only loop of the Streeter end moraine in Burleigh County, here named the Florence Lake loop, occurs along the Burleigh-Sheridan County line. The Streeter end moraine is a prominent ridged accumulation of drift with several arcuate looped segments.

The Florence Lake loop is a high till ridge with a gravel ridged outer margin, and numerous parallel superimposed till ridges. The loop has about 50 feet of relief with a maximum of 100 feet. The superimposed ridges are 10 to 50 feet high and are from 700 to 2500 feet apart. A collapsed outer part of the loop suggests that part of the end moraine was deposited on stagnant ice, and this part was mapped as collapsed end moraine.

Collapsed outwash topography occurs on the distal side of the Florence Lake loop from Pelican Lake in Burleigh County to the interlobate area with the West Woodhouse Lake loop in Sheridan County. A breach in the loop northeast of Pelican Lake in sec. 6, T. 144 N., R. 76 W. is now occupied by a collapsed outwash train.

The distal side of the Florence Lake loop merges into dead-ice moraine and collapsed outwash. The West Woodhouse Lake loop in Sheridan County is fronted by an outwash plain that extends into northeastern Burleigh County.

Subdued-end moraine. — End moraine of a transitional nature between end moraine and ground moraine was mapped as subdued-end moraine in Townships 141 and 142 north.

Subdued-end moraine is defined as a subdued ridgelike accumulation of till with moderate relief of 20 to 40 feet per square mile deposited along the margin of an active glacier.

The Long Lake subdued-end moraine is at elevations between 1900 and 2000 feet and has a knob and kettle topography in an over all linear trend. The moraine slopes gently to the east with a relief of 10 to 30 feet. The moraine resembles a collapsed moraine formed after the deposition of the north loop of the Long Lake end moraine. The subdued-end moraine is composed of till with numerous boulders on the surface. The boundary with the ground moraine is arbitrarily placed at an abrupt change in slope at the end moraine contact.

Ground moraine. — A small area of ground moraine in T. 142 N., R. 75 W. has less than 10 feet of relief. Much of the area contains small potholes floored by postglacial sediments.

Proglacial Landforms

Meltwater channels. — Three prominent channels draining meltwater from the Burnstad ice breached bedrock divides near the western margin of the Missouri Coteau district.

A meltwater channel in secs. 23 and 24, T. 142 N., R. 76 W. has been discussed in the section on kame terraces. This channel probably formed as an ice-marginal channel since its course lies between the dead-ice moraine and the north loop of the Long Lake end moraine. The channel bottom is about 50 feet below the crest of the end moraine and about 30 feet below the general level of the dead-ice moraine. The deposits in the channel are composed of outwash and alluvium. At its west end the bottom of the channel is about 40 feet higher than that of a deep north-trending meltwater channel which heads near Wing, and forms the upper

East Branch of Apple Creek. This channel was probably formed by meltwater confined between walls of ice. South of Wing the channel flows throuh dead-ice moraine for about three miles, then it cuts through a ridge of the Cannonball Formation. The channel is very narrow, especially in the dead-ice moraine.

East of Lake Canfield in T. 143 N., R. 77 W. a spillway cuts through a ridge of the Tongue River Formation. The channel is 60 to 120 feet below the crest of the bedrock ridge and is floored with sheetwash and alluvium. Beyond the bedrock ridge the meltwater channel separates into two segments, a minor segment trending southwest and a main segment trending through Lake Canfield. South of Lake Canfield the two rejoin and flow into the East Branch of Apple Creek. The main segment in the Lake Canfield area is marked by large shallow kettles with 10 to 20 feet of relief.

Outwash plain. – East of Salt Lake is an outwash plain with a few small kettles along the Burleigh-Sheridan County line. In the Salt Lake area the outwash plain merges into collapsed outwash on the distal side of the Florence Lake loop. The elevation of the plain is near 1960 feet with about 10 feet of relief.

Painted Woods Creek meltwater channel contains an outwash plain which extends from Johns Lake in Sheridan County south for two miles into Burleigh County. The outwash plain merges into outwash valley floor in Burleigh County, and in Sheridan County it merges into collapsed outwash topography. The plain has about 10 feet of relief, has surface elevations of 1850 to 1870 feet, and contains a few kettles.

Non-glacial Landforms

Lakes and drainage. – South and southeast of Arena numerous saline lakes occur in collapsed outwash topography and ground moraine. Harriet Lake is the largest saline lake in this area. Numerous saline and fresh lakes in the dead-ice moraine are Twin Lake, Horseshoe Lake, Lone Tree Lake, Obrien Lake, and Canfield Lake. In the collapsed outwash topography on the distal side of the Florence Lake loops are Florence Lake, Pelican Lake, Bunce Lake, and Salt Lake.

This district is characterized by non-integrated drainage, with short streams draining into lakes and kettles.

GENERAL STRATIGRAPHY - SUBSURFACE BEDROCK

Precambrian Rocks

The oldest rocks in Burleigh County are Precambrian granites. Five petroleum exploration wells have bottomed in pink to reddish-brown or gray granite at depths of from 6,100 feet in southeastern Burleigh County to 8,000 feet in the west.

Paleozoic Rocks

CAMBRO-ORDOVICIAN ROCKS

The Deadwood Formation of Cambro-Ordovician age consists of about 200 to 335 feet of glauconitic sandstones, limestones and shale. The Deadwood unconformably overlies Precambrian rocks and is unconformably overlain by Middle Ordovician rocks.

ORDOVICIAN ROCKS

Ordovician rocks are represented by, in ascending order: the Winnipeg, Red River, Stony Mountain and Stonewall Formations. The Winnipeg consists of a basal sandstone and an overlying shale. The Red River consists of limestone and dolomite, and the Stony

ERA	SYSTEM	SERIES	GROUP	FORMATION	THICKNESS (Feet)	LITHOLOGY
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	Colorado	Niobrara Carlile	450-575	Shale Shale
				Greenhorn Belle Fourche	320-375	Shale Limestone Shale
		LOWER CRETACEOUS	Dakota	Mowry Newcastle Skull Creek	250-320	Shale Sandstone Shale
				Fall River Lakota	110-300	Sandstone Sandstone
	JURASSIC			Swift Rierdon Piper	400-630	Shale Shale Limestone Anhydrite
PALEOZOIC	PENNSYLVANIAN		UNC.	Minnelusa	0-118	Sandstone
				Amsden	0-300	Dolomite
				Tyler	115-170	Shale Sandstone
	MISSISSIPPIAN		UNC. Big Snowy	Kibbey	0-35	Siltstone-Lime
			Madison	Poplar Interval	0-150	Evaporite
				Ratcliffe Interval	90-160	Limestone
				Frobisher-Alida Interval	170-215	Limestone
				Tilston Interval	105-140	Limestone
				Bottineau Interval	480-625	Limestone
				Bakken	0-25	Shale Limestone
	DEVONIAN	UPPER DEVONIAN	UNC.	Three Forks	0-20	Siltstone Shale
			Jefferson	Birdbear	40-80	Limestone
				Duperow	150-215	Limestone
		MIDDLE DEVONIAN	Manitoba	Souris River	25-135	Dolomite Limestone
				Dawson Bay	0-100	Dolomite
			Elk Point	Prairie	0-45	Evaporite
				Winnipegosis	0-100	Limestone
	SILURIAN		UNC.	Interlake	50-240	Dolomite
	SILURO-ORDOVICIAN			Stonewall	50-70	Limestone Dolomite
	ORDOVICIAN		Big Horn	Stony Mountain	150-170	Limestone Shale
				Red River	590-660	Limestone Dolomite
				Winnipeg	185-220	Shale Sandstone
	CAMBRO-ORDOVICIAN		UNC.	Deadwood	200-335	Shale Sandstone
	PRECAMBRIAN		UNC.			Granite

Figure 8. Burleigh County subsurface bedrock stratigraphic column.

Mountain consists of limestone and shaly limestone. The Stonewall Formation, of Upper Ordovician to Silurian (?) age, consists of limestone and dolomite. Ordovician rocks range in thickness from about 975 to 1120 feet.

SILURIAN ROCKS

The Interlake Formation of Silurian age consists of from 50 to 240 feet of dolomite and limestone. The Interlake Formation is unconformably overlain by rocks of Middle Devonian age.

DEVONIAN ROCKS

The Devonian rocks have been divided into seven formations which in ascending order are: Winnipegosis, Prairie, Dawson Bay, Souris River, Duperow, Birdbear, and Three Forks Forma-

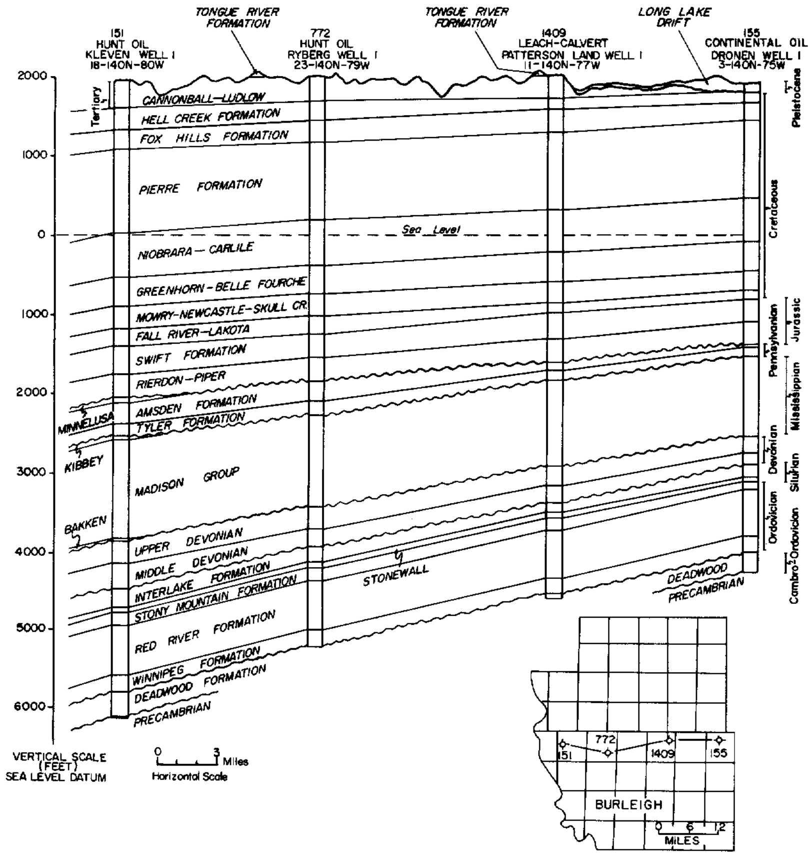

Figure 9. Burleigh County subsurface bedrock stratigraphic cross-section.

tions. The Winnipegosis and Prairie Formations consist mainly of limestone with some anhydrite. The Dawson Bay and Souris River Formations consist of limestone and dolomitic limestone. The Duperow and Birdbear Formations are also mainly limestones. The Three Forks Formation consists of siltstone and shale. Devonian rocks thin somewhat southeastward due to depositional thinning and to post-depositional erosion. Only the Birdbear, Duperow, Souris River and Prairie Formations are present throughout Burleigh County (S. B. Anderson, personal communication). Devonian rocks range in thickness from about 200 to 600 feet.

MISSISSIPPIAN ROCKS

Mississippian rocks have been divided into the Bakken Formation, the Madison Group, and the Big Snowy Group. The Bakken Formation consists of shale and limestone. Previously the Madison Group was divided into the Lodgepole, Mission Canyon, and Charles Formations, but now it is generally divided into five marker bed defined intervals (Smith, 1960, p. 959). The Madison Group consists mainly of limestone with some interbedded anhydrite. The Big Snowy Group is present only in the western part of Burleigh County where the Kibbey Formation is represented by limestone and a little shale. Mississippian rocks thin southeastward due mainly to pre-Pennsylvanian erosion. Mississippian rocks range in thickness from about 880 to 1330 feet.

PENNSYLVANIAN ROCKS

Pennsylvanian rocks are divided into the Tyler, Amsden, and Minnelusa Formations. The Tyler Formation, which occurs throughout the county, consists of shale and sandstone. The Amsden Formation is composed of limestone, dolomite, and shale. The Minnelusa Formation, which is present only in western Burleigh County, is composed of sandstone and shale. Pennsylvanian rocks thin southeastward due to pre-Jurassic erosion and range from about 110 to 560 feet thick.

Mesozoic Rocks

JURASSIC ROCKS

Rocks of Jurassic age have been divided into the Piper, Rierdon and Swift Formations. The limestones, shales, and anhydrites of the Piper Formation at the base of the Jurassic are overlain by the Rierdon Formation, which is composed mainly of shale. The Swift Formation consists of shale, sandstone, and siltstone. Jurassic rocks range in thickness from 400 to 630 feet.

CRETACEOUS ROCKS

In Burleigh County, Cretaceous rocks which do not crop out at the surface, or subcrop beneath glacial drift, have been divided into the Dakota and Colorado Groups. The Dakota Group is composed of quartzose sandstones of the Lakota and Fall River Formations, shale of the Skull Creek Formation, sandstone of the Newcastle Formation, and shale of the Mowry Formation. The Dakota Group ranges in thickness from 360 to 620 feet in Burleigh County. The Colorado Group consists of shale of the Belle Fourche Formation, shale and shaly limestone of the Greenhorn Formation, shale of the Carlile Formation, and calcareous shale of the Niobrara Formation. In Burleigh County, the Colorado Group ranges in thickness from about 770 to 950 feet.

DETAILED STRATIGRAPHY – SURFACE BEDROCK

Mesozoic Rocks

UPPER CRETACEOUS ROCKS – MONTANA GROUP

The Montana Group in North Dakota consists of the Pierre and Fox Hills Formations. Both are present in Burleigh County, but only the Fox Hills is exposed. Detailed lithologic descriptions of some exposures are provided in Appendix A.

Pierre Formation

The Pierre Formation, a marine shale of Late Cretaceous age, is composed of medium dark gray to light gray shale. It ranges in thickness from 946 to 1,020 feet in Burleigh County with only the uppermost part sub-cropping beneath the drift. The contact with the overlying Fox Hills Formation is gradational and is difficult to pick. The Pierre is overlain by the Fox Hills except in parts of Badger Creek and Cannonball River Channels (pl. 2 and test hole 1938) in southeastern Burleigh County, where the Pierre is overlain by glacial drift.

The Pierre Formation was penetrated in eight test holes. A structure map (fig. 11) was drawn using the information from

ERA	SYSTEM	SERIES	GROUP	FORMATION	THICKNESS	LITHOLOGY
CENOZOIC	TERTIARY	PALEOCENE	Ft. Union	Tongue River	0-215 Feet	Sandstone Shale Lignite
				Cannonball Ludlow	0-340 Feet	Sandstone Siltstone Shale Lignitic Shale
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS		Hell Creek	0-280 Feet	Mudstone Sandstone Lignite
			Montana	Fox Hills	0-300 Feet	Sandstone Shale
				Pierre	946-1020Feet	Shale

Figure 10. Burleigh County surface bedrock stratigraphic column.

these tests and from 14 petroleum exploration wells. The regional dip of the Pierre Formation to the west and northwest amounts to about 12.5 feet per mile, but in northeastern Burleigh County the regional dip is slightly reduced due to local structural influences.

Fox Hills Formation

The Fox Hills Formation, a marine sandstone of Late Cretaceous age, is exposed in the southeastern part of Burleigh County near Long Lake (pl. 1), but is better exposed to the south in Em-

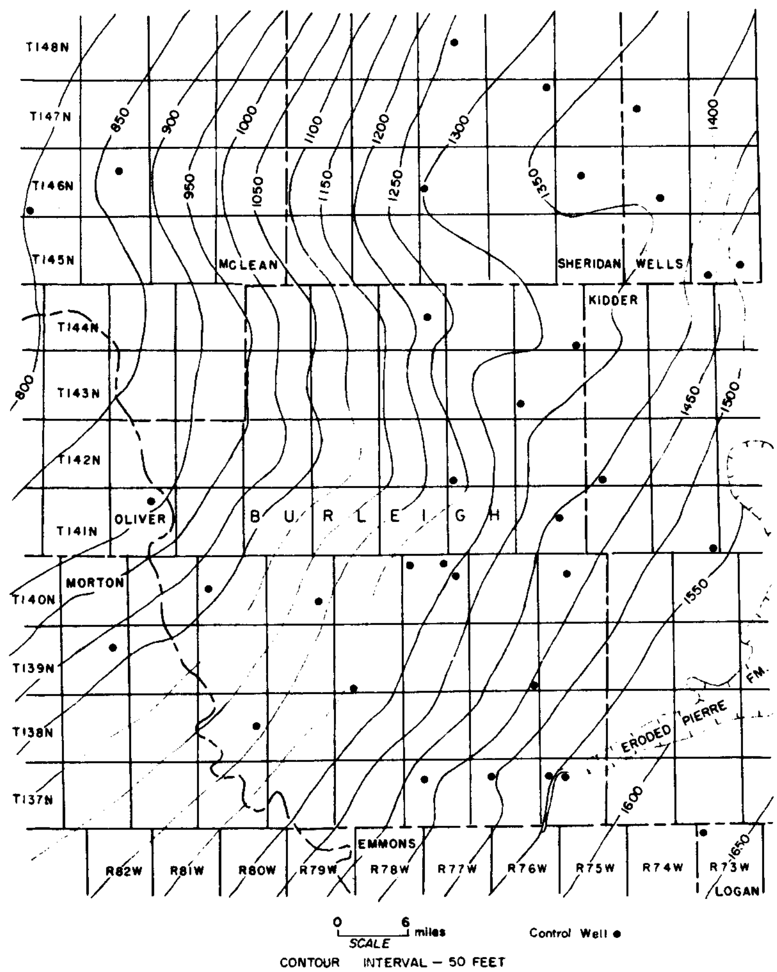

Figure 11. Structure contour map on the Cretaceous Pierre Formation.

mons County. In that area, Fisher (1952) recognized an upper and a lower sequence in the Fox Hills Formation. He further recognized a division of the lower sequence into a lower Trail City Member and an upper Timber Lake member, following the work of Morgan and Petsch (1945) in north-central South Dakota. Morgan and Petsch also divided the upper sequence into some thin bedded sandstones which they referred to as the "Banded Beds", and an overlying unit called the "upper sandstone".

The Fox Hills Formation was penetrated in 48 test holes. Seven petroleum exploration tests also provided some data. The Fox Hills consists of several sequences of interbedded sandstones and shales. In test holes 1830, 1857, and 1864 the Fox Hills can be divided into four lithologic units of alternating shales and sandstones, which are somewhat similar to the units previously recognized in surface work to the south of this area. Sandstones of the Fox Hills are friable except for siliceous beds which contain numerous ironstone concretions. In areas of cross-bedded sandstones, the Fox Hills contains carbonaceous and ferruginous material along the bedding planes. Bedding ranges in thickness from 1 mm to 1 m. The varicolored shales also contain occasional streaks or thin beds of carbonaceous material.

The Fox Hills Formation is directly overlain by glacial drift in many buried glacial channels and also in the Missouri River Trench in southwestern Burleigh County (pl. 2 and 7). In other areas the Fox Hills Formation is conformably and gradationally overlain by the Hell Creek Formation. The lower contact of the Fox Hills is placed at the top of a medium gray to grayish-black shale of the Pierre, and the upper contact is at the base of the lowermost lignite or carbonaceous shale in the Hell Creek Formation. The contact between the Hell Creek and Fox Hills Formation was cored in test hole 2047.

A structure contour map (fig. 12), shows the regional dip of the Fox Hills Formation to the west and northwest to be about 14.6 feet per mile in southern Burleigh County and about 13.6 feet per mile in the central part. In the eastern part of the county the regional dip is slightly less due to local structures.

The upper part of the Fox Hills Formation is exposed in southeastern Burleigh County, especially north of Long Lake. A roadcut in SW 1/4 SE 1/4 sec. 11, T. 137 N., R. 76 W. shows sandstone beds as thin as 1 mm that are probably equivalent to the "Banded Beds" as recognized by Morgan and Petsch (1945) in South Dakota. Test holes 1827 and 1828, located one mile east of the outcrop in sec. 11, penetrated at least 200 feet of the Fox Hills Formation. Since this outcrop is 50 feet higher than the ground surface near the test holes, the Fox Hills Formation is about 250 feet thick in this area. Such a thickness represents nearly a complete section of the Fox Hills Formation (fig. 13).

Hell Creek Formation

The Late Cretaceous Hell Creek Formation is of continental origin except for the marine Brien member. The Hell Creek is exposed in southwestern and south-central Burleigh County along the banks of the Missouri River and in the bluffs south of Bismarck, Menoken, and McKenzie. The Hell Creek Formation directly underlies the glacial drift in the Wing Channel, in Lake McKenzie Basin, under much of the Long Lake moraine, and in the Missouri River Trench to the southwest, (pl. 2). Subsurface Hell Creek Formation relationships were interpreted from 65 test holes.

The Hell Creek consists of sandstones, mudstones, siltstones, carbonaceous shales, and lignite in surface exposures. The light

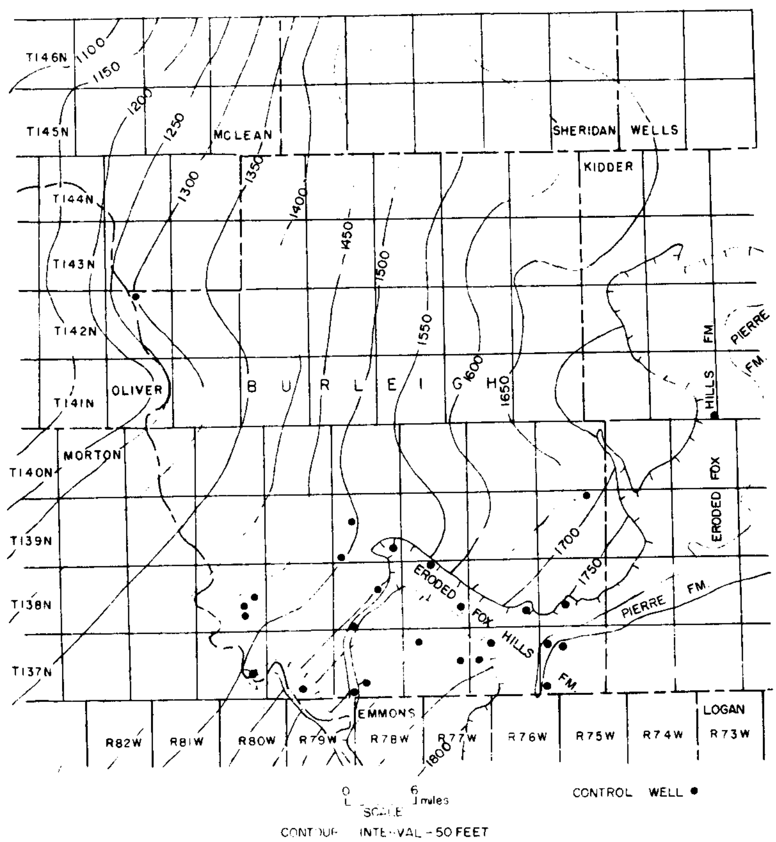

Figure 12. Structure contour map on the Cretaceous Fox Hills Formation.

gray and brown beds have commonly been referred to as the "Somber Beds" due to their distinctive colors.

The Hell Creek Formation consists of several sequences of interbedded gray, greenish-gray and brown shales, siltstones, and sandstones in the subsurface. The brownish shales contain abundant carbonaceous material and occasional thin lignite seams. The sandstones are friable, clayey, medium to fine-grained, and contain many dark minerals which give a "salt and pepper" appearance.

In northwestern Burleigh County, the Hell Creek is about 185 feet thick in test hole 1984, the only complete subsurface section of the formation found in test drilling. South of Bismarck the thickness is estimated at about 260 feet based on a measured

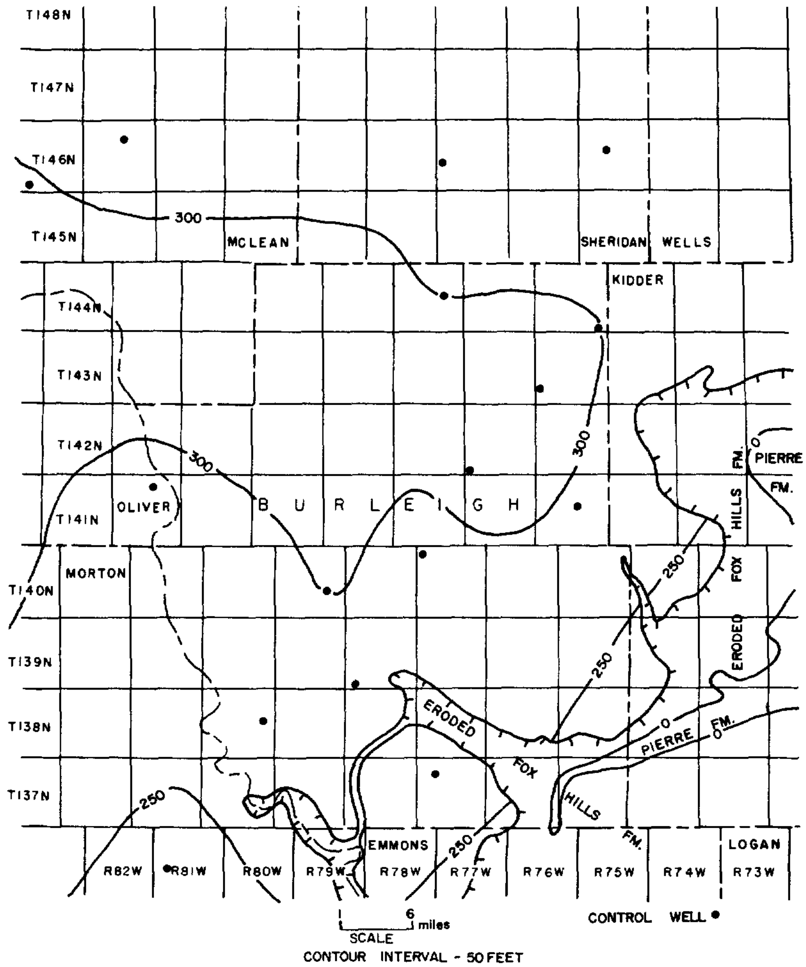

Figure 13. Isopach map of the Fox Hills Formation.

section in the SW 1/4 SE 1/4 sec. 26, T. 138 N., R. 80 W. and test hole 1857 two miles to the south. Eighty feet of the upper part of the Hell Creek Formation is exposed, and the contact with the overlying Tertiary Ludlow-Cannonball Formations is at an elevation of 1730 feet. The contact with the underlying Fox Hills Formation is at an elevation of 1467 feet in the test hole.

The formation contacts are conformable and gradational and have been placed at thin marker beds of lignite, lignitic shale, or carbonaceous shale. The lower contact is at the base of the "last lignite" of the Hell Creek Formation and the upper contact is at the base of the "first lignite" of the Ludlow.

Tertiary Rocks

PALEOCENE SERIES – FORT UNION GROUP

The Fort Union Group (Dorf, 1940) includes the Ludlow, Cannonball, and Tongue River Formations, all three of which are exposed in Burleigh County.

Ludlow Formation

The Ludlow Formation, a continental formation of Paleocene age, is exposed in southwestern and south-central Burleigh County. Although it occurs in areas where the upper part of the Hell Creek Formation crops out, it is not easily shown as a separate formation on the geologic map because it is very thin. Therefore, during the surficial mapping, the Ludlow Formation was included with its marine facies equivalent, the Cannonball Formation. Outcrops of the Ludlow are in secs. 26, 34, and 35 of T. 138 N., R. 80 W.; secs. 2 and 13 of T. 137 N., R. 80 W.; secs. 31 and 33, T. 139 N., R. 79 W.; and sec. 17, T. 138 N., R. 79 W. In the subsurface the Ludlow relationships were interpreted from test holes 1935, 1984, and 2026. The Ludlow Formation in the subsurface consists of olive black, carbonaceous and lignitic siltstone and shale, lignite, and micaceous friable sandstones.

The Ludlow Formation at the surface consists of interbedded yellow and brown sandstones, brownish-gray to black shales, and lignitic beds. The sandstones are friable and may contain shale partings and ferruginous sandstone concretions. The shales are fissile, non-calcareous, and carbonaceous. Two prominent lignitic beds are exposed, the lower one is a foot thick.

The Ludlow Formation in Burleigh County generally is about 13 feet thick. South of Bismarck in the bluffs along Apple Creek in SW 1/4 SW 1/4 sec. 26, T. 138 N., R. 80 W. the Ludlow is 19 feet thick, but the entire thickness was not exposed.

The contact of the Ludlow with the Cannonball Formation is conformable and gradational. The Ludlow Formation probably interfingers with the Cannonball as suggested by carbonaceous and lignitic shales interbedded with friable sandstones and shales which are lithologically similar to the Cannonball Formation. The Ludlow Formation is thin in Burleigh County, and thickens westward to 49 feet in Morton County (Laird and Mitchell, 1942, p. 17). They also state (p. 21) that the Cannonball Formation thins westward where it is replaced by the Ludlow.

Cannonball Formation

The Cannonball Formation, a marine formation of Paleocene age, is widespread in Burleigh County, but much of it is covered by drift. The best exposures are along the Missouri River Trench and the bluffs north and south of Bismarck, Menoken, and McKenzie. The Cannonball directly underlies the glacial drift along the north county line and throughout much of the east-central part of the county. The Cannonball relationships were interpreted from 38 test holes.

The Cannonball Formation at the surface consists of interbedded yellowish-brown, yellow gray, and olive gray sandstones, siltstones, shales, and lenticular limestones. The sandstones are friable, commonly non-calcareous, except where locally cemented and indurated, contain scattered ironstone concretions and dark mineral grains, which give it a "salt and pepper" appearance. The siltstones and shales are non-calcareous, flaky to fissile, and frequently sandy.

The Cannonball in the subsurface consists of interbedded olive, greenish-black and brownish-gray claystone, sandstones, siltstones, and limestone. The sandstones are friable, glauconitic, and non-calcareous. The claystones and siltstones are non-calcareous, with much macerated plant and carbonaceous material and scattered flakes of mica.

The Cannonball Formation in northwestern Burleigh County is about 340 feet thick, based on the elevation of the contact with the Ludlow Formation in test hole 1984 and the elevation of an exposed contact with the Tongue River Formation one mile east of the test hole. In east-central Burleigh County the formation is about 275 feet thick based on test hole 1935 and an exposed contact with the Tongue River Formation 1.5 miles west of the test hole.

Elevations of the contact with the Tongue River Formation taken from test holes 1939, 1990, and 2038 as well as from many contacts in outcrops show a regional dip to the west and northwest. It is estimated that the dip generally averages 12 to 14 feet per mile. Test holes 1985 and 1990 suggest a minor syncline in the Regan area (pl. 4, cross-section G-G^1).

The Cannonball contact with the overlying Tongue River Formation is sharp and disconformable as shown by local scouring. Excellent exposures of this contact are at the SE corner NW 1/4 sec. 13, T. 140 N., R. 81 (fig. 15), and NE 1/4 SE 1/4 sec. 11, T. 140 N., R. 80 W. The upper part of the Cannonball Formation is a sequence of interbedded siltstones, sandstones, shales, and an occasional lenticular limestone bed. Directly overlying this sequence is a massive, cross-bedded "basal sandstone" unit of the Tongue River Formation. Lenticular accumulations of rounded shale pebbles, probably derived from the Cannonball shale are interbedded with the "basal sandstone" unit adjacent to the contact. These sediments reflect the change in sedimentation from marine sea to continental alluvial plain deposition.

Fossils from the Cannonball Formation of Burleigh County, are not abundant, but during this study collections were made from three localities. Fossils from two of these sites had previously been reported by Holland and Cvancara (1958). Fossil crabs (**Camarocarcinus arnesoni**), petrified wood fragments, and shark teeth were collected from sand blowouts along roads bordering secs. 21 and 28, T. 137 N., R. 77 W. At a third locality (NE 1/4 SE 1/4 sec. 12, T. 141 N., R. 81 W.) pelecypod fragments and abundant **Halymenites** (fig. 14) were collected.

Tongue River Formation

The Tongue River Formation, a continental formation of Paleocene age, is exposed in the west-central part of the county. It is the youngest bedrock in Burleigh County, and it is found at the higher elevations. The Tongue River is best exposed north and west of Burnt Creek especially along the dissected valley wall of the Missouri River Trench district and in the areas of Keever Butte and the West Branch of Apple Creek.

The Tongue River Formation directly underlies the glacial drift near Wilton and Regan, but in most places the drift is thin and patchy with exposures of bedrock. The subsurface Tongue River Formation stratigraphy was interpreted from test holes 1985, 1990, 2005 and 2038.

The Tongue River Formation at the surface consists of a basal sandstone unit overlain by interbedded sandstones, claystones, siltstones, shales, limestone, and lignite. The basal sandstone unit is an excellent marker and was used to map the contact of the Tongue River and Cannonball Formations. This marker unit generally gives rise to sand blowouts in roadcuts (fig. 15).

The yellowish-gray, grayish-olive, and olive gray standstones of the basal unit are mostly friable, but partly indurated by calcareous or ferruginous cement. They are generally cross-bedded, medium to fine-grained with a few lenticular, fine to very fine-grained, sandstone beds. The sandstones contain fragments of petrified wood, abundant dark mineral grains and ironstone concretions. A shale and siltstone pebble conglomerate with a sand matrix, probably derived from the Cannonball Formation, is present locally near the formation contact. The upper part of the basal sandstone unit is resistant sandstone, sandy intraformational conglomerate, and sandy limestone. A section in the NW 1/4 NE 1/4 sec. 31, T. 141 N., R. 80 W. shows the base of the resistant beds to be about 108 feet above the top of the Cannonball Formation. The resistant beds at this site are 46 feet thick but the upper part is missing because of erosion.

Overlying the basal sandstone unit are interbedded shales, claystones, and lignite. The yellowish-orange, dusky yellow, and brownish-black shales and claystones are commonly silty and calcareous, flaky to fissile, locally interbedded with sandstones, and occasionally carbonaceous with abundant plant fragments and seams of lignite. The freshwater limestone is sublithographic, argillaceous, and lenticular. Occasionally, it is stained with ferruginous material. The limestone is highly fractured and weathers into rubble.

The Tongue River Formation in the subsurface consists of a basal sandstone unit overlain by interbedded shales, claystones, siltstones, and lignite. The basal sandstone is friable except for minor indurated beds. The sands are coarser in the lower part

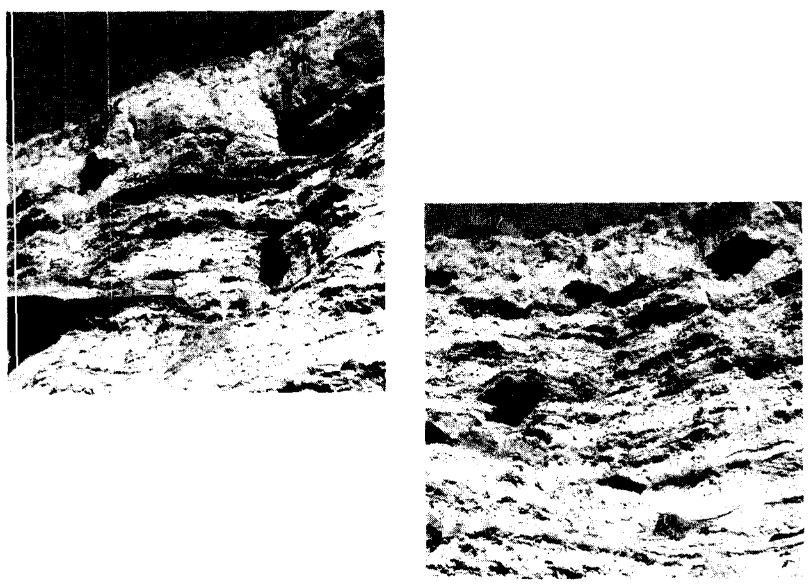

Figure 14. – Abundant **Halymenites** in lenticular sandstone and sand of the Cannonball Formation. NE 1/4 SE 1/4 sec. 12, T. 141N., R. 81W., Burleigh County.

of the formation. The yellowish-brown, olive gray, and brownish-black shales, claystones, and siltstones are soft, calcareous, and interbedded with thin lignite seams.

The Tongue River Formation in northwestern Burleigh County is represented only by the lower part of the formation. At Wilton the Tongue River Formation is 215 feet thick in test hole 1985. At Regan the Tongue River Formation is 68 feet thick in test hole 1990. Near its southern limit in Burleigh County the Tongue River Formation is 130 feet thick as shown by test hole 2038 which peneterated 105 feet of Tongue River sediments 25 feet below the top of the outcrop. This variable thickness is due to erosion of the upper part of the formation.

Fossils collected from 11 sites in the Tongue River Formation (fig. 16), include gastropods, pelecypods and ostracods. Vertebrates are represented by fish bones and teeth. Petrified wood is abundant in the basal sandstone. Tongue River fossils frequently are found in the drift and snail shells are locally abundant in gravels.

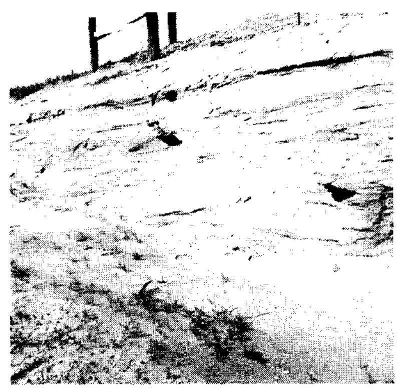

Figure 15. – Contact of the Cannonball and Tongue River Formations is at the base of shovel in left photo. SE corner NW 1/4 sec. 13, T. 140 N., R. 81, Burleigh County. Described in measured section 5-62, Appendix A.

1.	NE cor.	12-141N-80W
2.	NE cor. NW	26-141N-80W
3.	NW cor. SW	7-143N-79W
4.	NW cor. NE	12-141N-79W
5.	0.1 mi. N of SW cor.	10-142N-78W
6.	NW cor. NE	29-142N-78W
7.	0.2 mi. E of SW cor.	14-142N-78W
8.	0.2 mi. E of NW cor.	30-142N-78W
9.	SE cor.	5-142N-77W
10.	0.2 mi. N of center	33-141N-80W
11.	0.2 mi. N of SW cor.	23-141N-80W

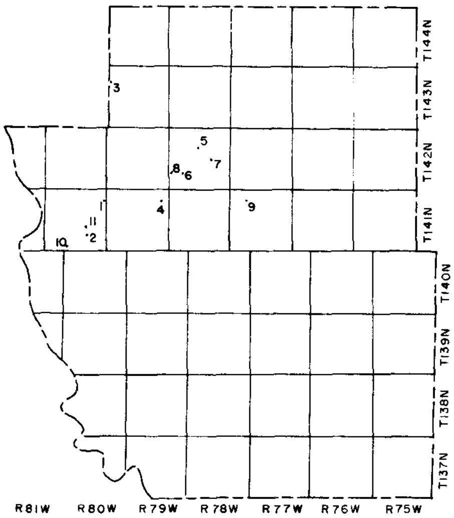

Figure 16. Locations of the Tertiary Tongue River Formation fossil sites in Burleigh County.

GLACIAL DEPOSITS

Pleistocene Series

The unit of geologic time during which glacial and post-glacial materials were deposited is the Pleistocene Epoch. The time-stratigraphic equivalent is the Pleistocene Series. In Burleigh County glacial deposits are referred to two subdivisions of the Pleistocene Epoch, the Wisconsin Age and Recent Age. The time-stratigraphic equivalents are the Wisconsin Stage and Recent Stage. Stages older than the Wisconsin may be present in the county but evidence for their recognition is lacking. Four radiocarbon dates have been obtained in Burleigh County, but correlations in Burleigh County are based mainly on comparisons with previous work in south-central North Dakota.

Wisconsin Stage

The drift sheets in Burleigh County range in age from early (?) to late (?) Wisconsin. The Napoleon Drift which overlies bedrock in western Burleigh County is early (?) Wisconsin and the Long Lake and Burnstad Drifts, are late (?) Wisconsin.

LITHOSTRATIGRAPHY

The similarity in lithology of Burleigh County drifts is shown by various analyses. Color and grain size are nearly identical, making differentiation on the basis of lithostratigraphy difficult.

Drift Analysis

Stone counts. – Thirty-four samples of pebbles from Burleigh County (fig. 17) were studied and the results are tabulated in Table 3. The pebbles were collected from fresh till surfaces containing about 100 pebbles. Pebbles of approximately one-half to one inch and larger were collected. Shale and friable lithologies were tabulated in the field and the remaining pebbles were identified later.

Limestones and dolomites are the most abundant lithology in every sample except three in which shale was the major constituent and limestones and dolomites were next. Shale was second in abundance in fourteen samples and granite was second in eleven samples.

By grouping the pebbles into limestones and dolomites, igneous and metamorphics, and local bedrock types, they can be plotted as shown in figure 18. Howard (1960, p. 39-40) used pebble analyses in differentiating individual drift sheets in northwestern North Dakota and the plots of the various drifts in Burleigh County indicate some apparently significant trends. The Napoleon Drift

Sample No.	Location
1.	SE SW 12-140N-75W
2.	NE NE 36-141N-75W
3.	NW SW 28-139N-76W
4.	SW NE 20-138N-75W
5.	NE NE 13-138N-76W
6.	SE SW 19-140N-76W
7.	SW SW 4-139N-76W
8.	SE SE 23-140N-76W
9.	NE NE 11-139N-76W
10.	NE NE NW 12-140N-76W
11.	NW NW NW 25-141N-76W
12.	NW NW 22-138N-79W
13.	NE NW 10-139N-80W
14.	NW NE 28-140N-79W
15.	SE SW SW 21-141N-75W
16.	SE NE NE 12-142N-76W
17.	SE SE NE 30-142N-75W
18.	SE SE SW 4-141N-75W
19.	SE SE NE 16-140N-77W
20.	SW SE 36-139N-75W
21.	NW NW 36-137N-75W
22.	NE NW NE 7-140N-78W
23.	NE NE SE 3-139N-79W
24.	SE SE SE 10-144N-75W
25.	NW NW NW 14-143N-76W
26.	SE SE SE 22-143N-75W
27.	NE NE SE 6-144N-76W
28.	NW NW NW 34-144N-77W
29.	SW NW SW 30-144N-77W
30.	NE NE NE 7-144N-77W
31.	SW SW NW 30-144N-79W
32.	NE NE 7-142N-79W
33.	NE NE NW 20-141N-78W
34.	SE SE SE 21-142N-78W

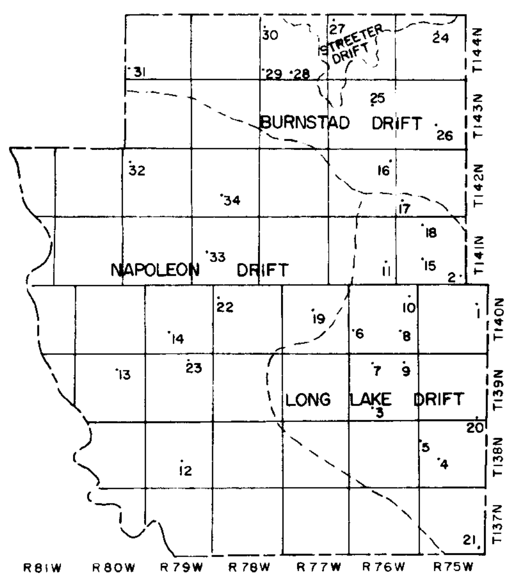

Figure 17. Drift boundaries and sample localities in Burleigh County.

is low in igneous and metamorphic pebbles, containing less than twenty-five percent and as low as five percent of this fraction, but it shows high counts of local bedrock types and limestones, probably due to the occurrence of this drift as scattered patches over bedrock. The Long Lake Drift appears transitional from a local bedrock influence to one containing more of other rock types probably due to there being fewer areas of bedrock exposures in areas of Long Lake Drift, than in areas of Napoleon Drift. The lithology of the Burnstad Drift, including the Streeter Drift, is influenced least by local bedrock.

The Long Lake Drift has a greater abundance of shale pebbles than the other drifts. This is probably due to a different direction of ice movement with the movement being from the east and north over the Cretaceous shale.

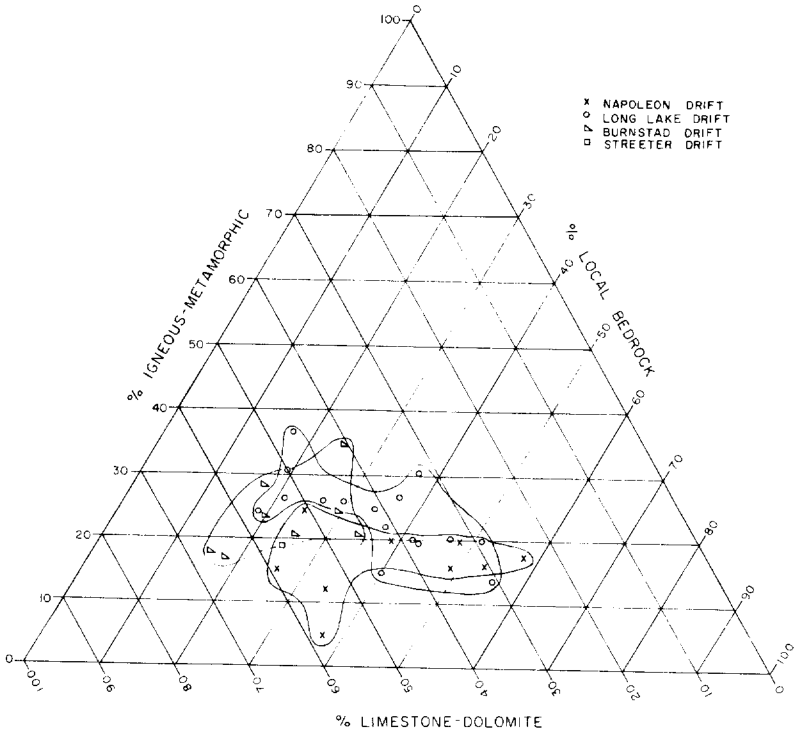

Figure 18. Triangular diagram showing pebble lithology of 34 samples in Burleigh County.

Sample No.	Granite	Quartzitic	Basic	Foliated Metamorphic	Limestone Dolomite	Sandstone	Shale	Chert	Iron Concretion	Clay	Miscellaneous	Number of Pebbles Counted
1	17.0		2.0	1.0	29.0	10.0	35.0		6.0			100
2	12.2	1.0	11.2	1.0	40.8	5.1	15.3	7.2	6.2			98
3	13.4	0.9	4.5	1.8	33.0	2.7	34.7	2.7	0.9	4.5	0.9	112
4	15.1	1.0	1.0	3.0	38.4	2.1	34.3	2.1	3.0			99
5	9.8	1.0	2.9	1.0	45.1	5.9	20.6	2.0	7.8	3.9		102
6	10.8	1.0	7.8	2.0	41.2	7.8	9.8	4.9	11.8	2.9		102
7	15.8	2.1	12.6		32.6	7.4	27.4		2.1			95
8	25.4		9.4	1.9	46.3	1.9	15.1					106
9	8.9		4.9		30.7	1.0	46.5	2.0	4.0	2.0		101
10	17.0	0.9	1.9		37.8	4.7	28.3	6.6	2.8			106
11	16.7	0.9	9.2		37.0	4.7	19.4	0.9	6.5	4.7		108
12	9.7		10.7		40.8	2.9	11.7		15.5	8.7		103
13	5.1		11.1		30.3	3.0	5.1	2.0	19.2	22.2	2.0	99
14	13.9		10.9		50.5	5.9	5.9	1.0	7.9	4.0		101
15	19.0	1.0	5.0	1.0	45.0	2.0	23.0		1.0	3.0		100
16	17.3	1.0	6.7		46.2		16.3	2.9	7.7	1.9		104
17	16.5		10.1		52.3		9.2	0.9	6.4	4.6		109
18	15.4		12.5	2.9	50.0	4.8	3.8	1.0	6.7	2.9		104
19	2.0		3.0		57.5	5.9	1.0		16.8	7.9	5.9	101
20	11.6		12.6		56.8	4.2	8.4		5.3	1.1		95
21	15.1		10.4	0.9	47.2		11.3	3.8	9.4	1.9		106
22	5.0	2.0	5.0		54.0	3.0	19.0	1.0	9.0	1.0	1.0	100
23	7.0		7.0	1.0	59.0	4.0	15.0		4.0	1.0	2.0	100
24	8.2	2.0	10.2		54.1		13.2	4.1	6.2	2.0		98
25	25.8	1.0	7.9		40.6	5.9	6.9	3.0	6.9	2.0		101
26	12.3	4.1	10.2	2.0	54.1	4.1	5.1	1.0	5.1		2.0	98
27	12.6	1.9	2.9	1.9	56.3		8.7		4.0	10.7	1.0	103
28	9.8		6.9	1.0	66.6	2.0	1.0	3.9	5.9	2.9		102
29	13.4	2.9	6.7	1.0	56.7		10.6	1.0	4.8	1.9	1.0	104
30	8.0	1.0	8.0		65.0		13.0		1.0	4.0		100
31	11.9	2.0	5.9	1.0	45.5	3.0	26.7		2.0		2.0	101
32	12.9		4.9		24.8	10.9	20.8	15.8	8.9		1.0	101
33	6.0	1.0	12.0	1.0	32.0	20.0	3.0		22.0	3.0		100
34	6.9	1.0	7.9		35.3	8.8	22.5	1.0	2.9		13.7	102

TABLE 3. – Glacial pebble analyses in Burleigh County. Lithology expressed as percent of total sample.

Grain size. – Thirty-three samples of till from Burleigh County were mechanically analyzed for grain size, using the hydrometer method to determine the silt and clay fraction and the sieve analysis for the sand fraction. Particles greater than sand size were not included in the analysis. Results are tabulated in Table 4.

Sand-silt-clay percentages were determined for thirty-three samples. Sand is most abundant in seventeen samples, silt in seven

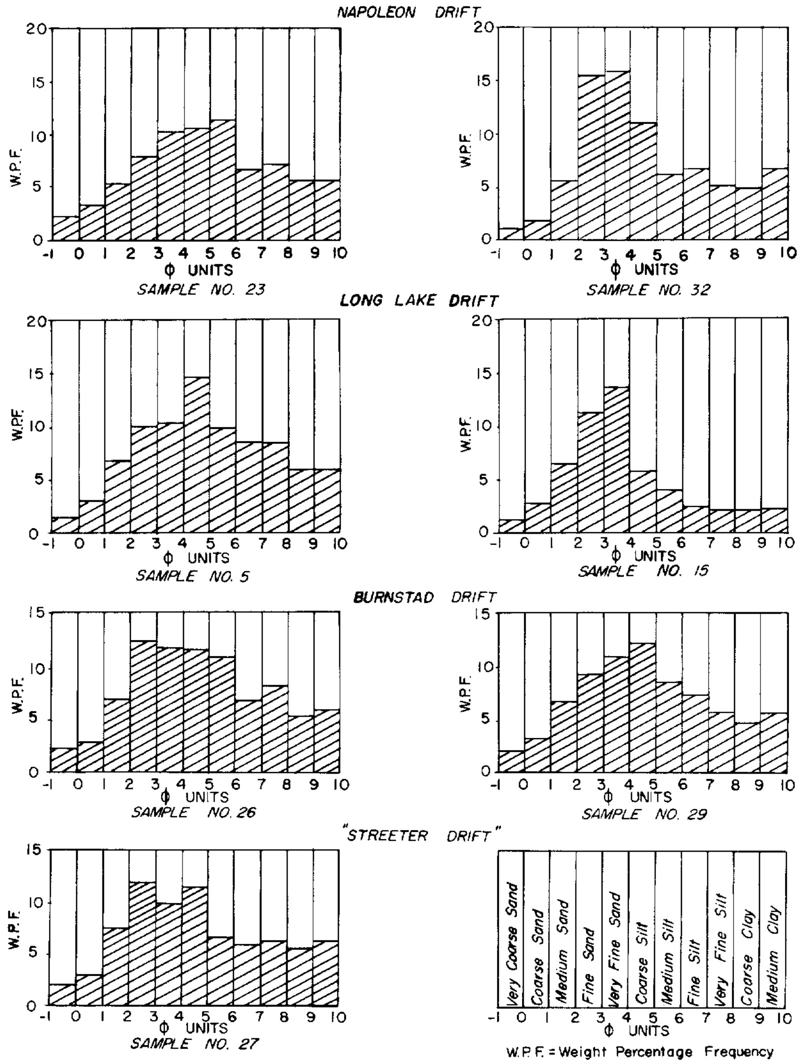

Figure 19. Histograms showing grain size frequencies in 7 samples of till in Burleigh County.

samples, and clay in nine samples. Seven of the thirty-three samples were tested for the distribution of particle sizes from very coarse sand to medium clay according to the Wentworth classification (fig. 19). One sample was highest in medium silt and two samples were highest in each of the coarse silt, fine sand, and very fine sand sizes. The sand-silt-clay ratios were plotted on triangular coordinate diagrams (fig. 20) and the results indicate little difference in grain size between the various tills.

The Napoleon Drift has four samples higher in clay than any others. Five out of nine Napoleon Drift samples had a higher percentage of clay than silt or sand. In the Long Lake Drift twelve samples out of fifteen show the sand fraction to be the greatest. The other three samples were highest in silt. In the Burnstad Drift, five out of eight samples show nearly equal sand-silt-clay ratios, and three samples were higher in sand and silt.

Shepps (1953, p. 34) used mechanical analyses to correlate multiple tills. He concluded that grain size is generally finer in the younger tills. The results of the grain size analysis in Burleigh

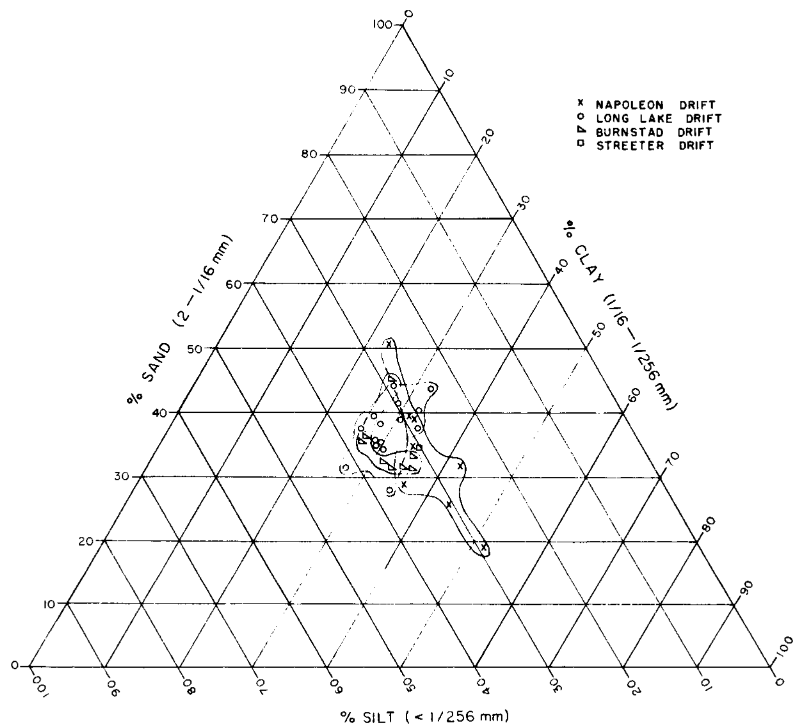

Figure 20. Triangular diagram showing grain size composition of 33 till samples in Burleigh County.

Sample No.	Sand	Silt	Clay	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt	Coarse Clay	Medium Clay
1	36.0	35.5	28.5											
2	44.0	29.0	27.0											
3	39.8	34.0	26.2											
4	35.9	34.7	29.4											
5	31.7	41.6	26.7	1.4	3.1	6.8	10.1	10.3	14.7	9.9	8.5	8.5	5.9	5.9
6	39.8	27.4	32.8											
7	34.4	35.8	29.8											
8	41.2	29.8	29.0											
9	37.8	28.7	33.5											
11	39.0	30.2	30.8											
12	34.2	31.2	34.6											
13	18.9	29.8	51.3											
14	31.5	26.2	42.3											
15	35.5	35.3	29.2	1.3	2.8	6.4	11.3	13.7	5.8	4.0	2.5	2.2	2.2	2.3
16	36.7	36.6	26.7											
17	38.4	33.6	28.0											
18	43.9	23.8	32.3											
19	25.6	30.6	43.8											
20	28.1	37.4	34.5											
21	38.0	36.5	25.5											
22	50.4	26.1	23.5											
23	28.9	35.9	35.2	2.2	3.3	5.3	7.9	10.2	10.7	11.3	6.7	7.1	5.6	5.6
24	32.1	35.0	32.9											
25	45.0	28.4	26.6											
26	36.0	37.3	26.7	2.2	2.8	6.9	12.3	11.8	11.7	10.8	6.7	8.1	5.2	5.9
27	34.2	30.6	35.2	2.0	2.9	7.5	11.9	9.9	11.5	6.7	5.9	6.3	5.7	6.3
28	33.6	31.2	35.2											
29	31.9	33.6	34.5	2.0	3.2	6.6	9.2	10.9	12.2	8.5	7.3	5.7	4.7	5.7
30	32.5	36.0	31.5											
31	30.9	33.9	35.2											
32	39.5	29.0	31.5	1.0	1.7	5.6	15.4	15.8	10.9	6.2	6.7	5.1	4.9	6.7
33	23.3	26.8	49.9											
34	39.4	29.0	31.6											

TABLE 4. – Grain size analyses of till in Burleigh County. Grain size expressed as percent of total sample.

County do not agree with this conclusion, as the older Napoleon Drift has more samples with a higher percentage of clay than do the younger Long Lake and Burnstad drifts. However, this does not necessarily refute his conclusions, as the number of analyses run in Burleigh County were probably not enough to adequately test his hypothesis. However, it is suggested that the grain size of the tills in Burleigh County are probably influenced more by local bedrock than by age of the tills.

Pebble orientation. — Orientation of pebbles was observed in a till exposure southeast of Wilton in NE 1/4 sec. 7, T. 142 N., R. 79 W. This site is a relatively flat upland in sheet moraine. The analysis is based on the orientation of 100 pebbles whose long axis measured at last twice the short axis. The preferred orientation is in a northeast direction. Holmes (1941, p. 1301) demonstrated that the long axes of pebbles tend to parallel the direction of ice flow. The ice flow in the Wilton area was from the northeast based on the pebble orientation. Lineations in the drift, and the drift borders provide further evidence to support this conclusion.

Composition of Drift

Till. — Till consists of sediments deposited directly by glacial ice and composed of unsorted, unstratified, and heterogeneous materials whose particle size ranges from boulder to clay.

The till in Burleigh County is generally light olive gray (5Y 5/2) when wet, and yellowish-gray (5Y 7/2) when dry, and is oxidized to depths of 20 to 30 feet. It is generally compact with joints absent or poorly developed. The zone immediately beneath the upper soil horizon frequently has a mottled appearance due to the concentrations of calcium carbonate and the undersides of free cobbles and pebbles are frequently encrusted with caliche. Rounded shale particles from sand to pebble size and lignite fragments are common. Boulder, cobble, and pebble content of the till is estimated at five percent, so the major fraction consists of sand, silt, and clay.

Boulders, common on the till surface, are relatively more numerous in eastern Burleigh County. Most of the boulders are granite, a few were derived from basic and metamorphic rocks. Boulders derived from local sandstones and siliceous rocks are generally rare except near bedrock outcrops. Limestone and dolomite boulders are occasionally found in eastern Burleigh County, but rarely in the west.

Glaciofluvial sediments. — Sediments deposited by meltwater streams and composed of washed, sorted, and stratified materials consisting mostly of sand and gravel, are classified as glaciofluvial sediments. Outwash, when used to mean any washed drift, is synonymous with glaciofluvial sediments.

The glaciofluvial sediments in Burleigh County are composed mainly of stratified sands and gravels. The size range is from fine sand to pebbles with coarse sand predominant.

The pebble composition is similar to that of till but with fewer shale pebbles. Boulders are rare in proglacial outwash but in ice-contact outwash deposits, boulders are quite common. Collapsed outwash and other ice-contact outwash deposits generally consist of poorly sorted boulders, cobbles, gravel, and sand. In ice-contact outwash the grain size generally ranges from granules to pebbles.

Glaciolacustrine sediments. — Sediments deposited in ice-walled, ice-marginal, or proglacial lakes, composed mostly of washed, sorted, and stratified materials consisting chiefly of silts and clays, are glaciolacustrine sediments.

The glaciolacustrine sediments in Burleigh County when moist and unoxidized are dark greenish-gray (5GY 4/1), olive gray (5Y 3/2) and medium bluish-gray (5B 5/1). The moist and oxidized sediments are dark yellow brown (10YR 4/2) and light olive gray (5Y 5/2). The sediments are mostly calcareous silts and clays in beds less than one inch thick.

MORPHOSTRATIGRAPHY

The drifts in Burleigh County are recognized by their surface form, geographic position, and inferred geologic history. The morphostratigraphic unit as proposed by Frye and Willman (1962, p. 112-113) was modified by Clayton (1962, p. 53). In this report a glacial morphostratigraphic unit is defined as a body of drift identified by its surface form and position, consisting of all the drift deposited by significant glacial advance. The basic unit is a drift rather than a moraine, although the glacial morphostratigraphic unit is generally named and identified by the major moraine with which it is associated. The three glacial morphostratigraphic units in Burleigh County are the Napoleon Drift, Long Lake Drift and Burnstad Drift.

Napoleon Drift

The Napoleon Drift was proposed as a morphostratigraphic unit by Clayton (1962, p. 56) who designated the type area in western Logan County. The Napoleon Drift covers portions of west and central Burleigh County. This glacial morphostratigraphic unit is recognized as chiefly sheet moraine, located in front of younger drifts to the north and east. The topography is that of a rugged, stream-dissected, bedrock upland with integrated drainage. Frequently, boulders provide the only evidence of former glacial activity.

Correlation. — The correlation of the Napoleon Drift has been discussed in detail by Clayton (1962, p. 59). Briefly, his correlations are: (1) morphostratigraphically with the "Tazewell (?)" drift of Lemke and Colton (1958, p. 47 and fig. 3); and (2) time-stratigraphically with the lower part of the Wisconsin Stage, because it is slightly weathered, has integrated drainage, is radiocarbon dated at older than 38,000 years (W-990), and is correlative with the Tazewell of South Dakota. The Napoleon may also be as young as 28,700 years (W-1045) which would place it in upper Wisconsin. Fossil gastropod and pelecypod shells in Napoleon glaciofluvial sediments have been dated at greater than 38,000 years (W-1433) in NE1/4 SW1/4 SW1/4 sec. 34, T. 139 N., R. 79 W. Burleigh County. Some reworked shells from the Tongue River Formation were present with the Pleistocene shells. An attempt was made to obtain only a Pleistocene shell collection, however, there exists the possibility of older shells in the sample.

A lower jaw of a large Pleistocene horse was found in Napoleon outwash by Dan E. Hansen, about six miles east of Bismarck, in SW1/4 NW1/4 sec. 35, T. 139 N., R. 79 W. (fig. 21). The jaw was identified by C. W. Hibbard of the University of Michigan (letters dated Jan. 29 and Feb. 26, 1962) as **Equus hatcheri** Hay (University of Michigan, Museum of Paleontology number 44573). Hibbard stated in his first letter that, "It seems to fit best with the late Kansan to Illinoian horses I have seen." In his second letter he states, "There is no reason why the large horse could not be Wisconsin. I have taken the large horses from Sangamon deposits. I have never taken it later, but James Quinn described one (**Equus scotti**) from a Wisconsin deposit in West Texas." Although the jaw fragment was found in Napoleon Drift, it is conceivable that it could have been derived from earlier deposits and may be of pre-Wisconsin age.

Long Lake Drift

The Long Lake Drift was proposed as a morphostratigraphic unit by Clayton (1962, p. 61) who designated the type area in the northwest corner of Logan County. The Long Lake Drift in Burleigh County is in the eastern part. This glacial morphostratigraphic unit is recognized as mainly end moraine and ground moraine, located between the Napoleon Drift and the Burnstad Drift. The topography is mainly due to glacial construction but several bedrock highs account for part of the surface relief. The Long Lake Drift is also distinguished from the Napoleon Drift on the basis of drainage development which is not completely integrated.

Correlation. — The correlation of the Long Lake Drift has been discussed by Clayton (1962, p. 62). Briefly, his correlations are: (1) morphostratigraphically with no other drift, although it may be correlative with the Zeeland Drift in southern McIntosh County; and (2) time-stratigraphically with the upper part of the

Wisconsin Stage, because it is overlapped by, and therefore older than the Burnstad or 11,500 years, and because it lacks integrated drainage. The Long Lake Drift probably is 12,000 to 13,000 years old.

The north loop of the Long Lake end moraine is truncated by Burnstad dead-ice moraine. This truncation has been interpreted as an overlap due to a significant readvance of Burnstad ice,

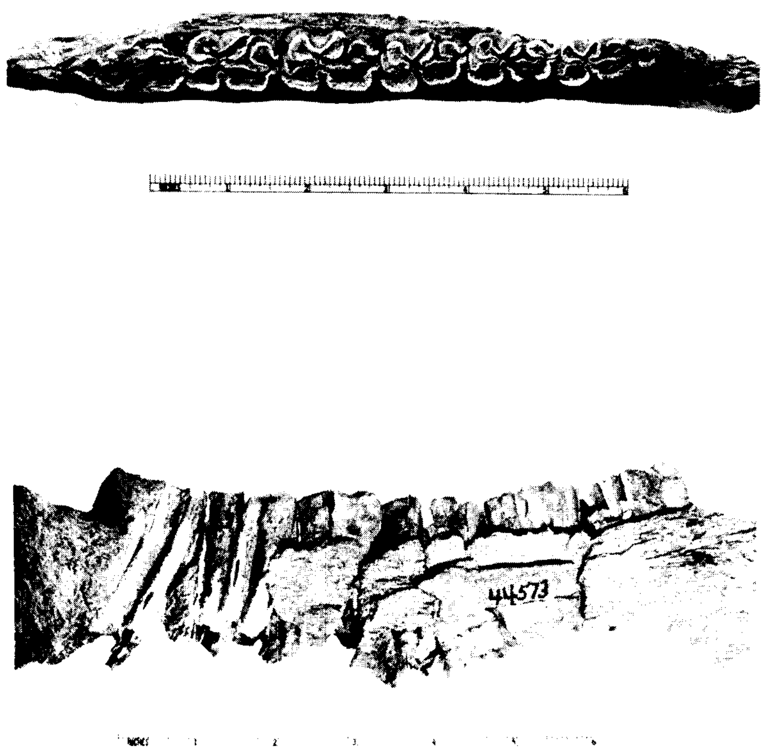

Figure 21. – Horsejaw of a large Pleistocene horse **(Equus hatcheri)** found in Napoleon Drift, SW1/4 NW1/4 sec. 35, T. 139 N., R. 79 W., Burleigh County (photo courtesy of C. W. Hibbard, Univ. Michigan).

(Clayton, 1962, p. 62-63), but the overlap may represent a minor readvance or an adjustment of the Long Lake glacier.

Burnstad Drift

The Burnstad Drift was proposed as a morphostratigraphic unit by Clayton (1962, p. 62-63) who designated the type area in west-central Logan County. The Burnstad Drift in Burleigh County is mostly in the north. This glacial morphostratigraphic unit is recognized as chiefly dead-ice moraine with collapsed outwash topography behind the Napoleon and Long Lake Drifts. Probably the main basis for distinguishing the Burnstad Drift is its inferred geologic history. It is distinguished from the Napoleon and Long Lake Drifts because it has non-integrated drainage. The topography is mainly due to glacial stagnation construction, but bedrock highs are a factor along its southern border. The prominent ridged Streeter end moraine is in the northeastern part of the county adjacent to the Burnstad dead-ice moraine. The Streeter Drift has been included in the Burnstad Drift by Clayton (1962, p. 63). Briefly, his reasons are: (1) these deposits are from a single significant advance which included the minor Streeter advance; (2) lithology and topography are similar; and (3) stagnant ice existed in front of the Streeter moraine while it was being formed. In Burleigh County Streeter collapsed outwash topography on the distal side of the Florence Lake loop overlies Burnstad dead-ice moraine. The Burnstad end moraine is not present in Burleigh County.

Correlation. — The correlation of the Burnstad Drift has been discussed by Clayton (1962, p. 66-68). Briefly, his correlations are: (1) morphostratigraphically with the "post-Tazewell-pre-Two Creeks" and "post-Cary maximum advance no. 1" of Lemke and Colton (1958, figure 3 and 4) and with the "Mankato" drift of Flint (1955, pl. 1); and (2) time-stratigraphically with the upper part of the Wisconsin Stage because of several radiocarbon dates which range from 11,650 $\pm$ 310 years (W-974) to 9,000 $\pm$ 300 years (W-1019).

Two radiocarbon age determinations by the U. S. Geological Survey on gastropod and pelecypod shells in Burleigh County Burnstad Drift gave ages of 9,990 $\pm$ 300 years B. P. (W-1436) in sec. 19, T. 143 N., R. 75 W. (site 10 in the section on fossils) and 10,100 $\pm$ 300 years B. P. (W-1434) in sec. 12, T. 144 N., R. 79 W. (site 8 in the section on fossils).

An alternate interpretation of the inferred glacial history has been discussed by Rau, and others, (1962, p. 27-32). Briefly, their interpretations are: (1) the south loop of Long Lake end moraine is truncated by Burnstad Drift; (2) Burnstad Drift is overlapped by the Lake George end moraine loop of the Streeter Drift; (3) Streeter Drift is bordered on the south by Burnstad Drift and on the west by Long Lake Drift; and (4) dead-ice moraine between the Long Lake end moraine and the Streeter end moraine is Streeter Drift.

Recent Stage

Sediments deposited in Burleigh County during the Recent Stage are generally difficult to distinguish from the postglacial Wisconsin Stage sediments. Recent sediments occur as alluvium in shallow depressions, sloughs, lakes, and floodplains. The floodplain alluvium of the Missouri River consists of channel bars and meander bars, formed and continually being modified by present stream action. The alluvium is composed mostly of sand, silt and clay. Postglacial eolian sand is probably Wisconsin and Recent. Sheetwash and colluvium deposits are Recent.

DRAINAGE HISTORY

Existing Drainage

The present integrated drainage system in south-central North Dakota consists of the Missouri River and its tributaries. The Missouri River tributary pattern is asymmetrical. The well-developed western tributaries in the Glaciated Missouri Slope district include the Knife, Heart, and Cannonball Rivers. The underdeveloped eastern tributaries in the Coteau Slope district are Snake Creek, Painted Woods Creek, Burnt Creek, Apple Creek, and Badger Creek. The drainage of the Missouri Coteau district is non-integrated.

MISSOURI RIVER

The drainage history of the Missouri River has been discussed by various workers (Warren, 1869; Leonard, 1912b; Todd, 1914; Alden, 1932; Benson, 1952; Flint, 1955; Howard, 1960; and Simpson, 1960) and a brief summary will be presented here.

The ancestral Missouri River flowed northeastward from the northwestern corner of North Dakota into Hudson Bay. As the continental glacial ice sheet advanced from the north the ancestral Missouri River was blocked, assumed an ice-marginal position, and was diverted to the southeast. The present channel of the Missouri River comprises segments representing preexisting river channels and segments of superposed drainage divide channels (pls. 7 and 8). The drainage divide channel segments are narrow, youthful valleys, whereas the preexisting river channel segments are broader, more mature valleys. The major preglacial drainage divides are shown on plate 7. The diverted Missouri River has captured many east flowing rivers on the Missouri Plateau of North and South Dakota. This has resulted in a one sided pattern of tributaries. This present channel probably was the second major diversion of the ice-marginal drainage in south-central North Dakota. Earlier the Missouri River had been diverted through a channel existing in Morton and Mercer Counties along Big Muddy Creek and Elm Creek.

Preexisting Drainage

The preexisting drainage in south-central North Dakota consisted of the preglacial and pre-Wisconsin drainage (pls. 3 and 7), and the diversion and Wisconsin drainage (pl. 8). In this report new names and definitions are applied to many of these channels for ease of discussion. A few of the channel names have been adapted from previous publications, but all of the channels have been redefined or extended in this report. The drainage in Burleigh County will be discussed in detail, that outside of the county will be mentioned briefly.

The preglacial and pre-Wisconsin drainage of south-central North Dakota consisted of the ancestral Knife River, Cannonball River, and Grand River systems (pl. 7). The ancestral Knife River system extends from McLean County into Sheridan and Burleigh Counties. The Cannonball River system including the smaller ancestral Heart River system, can be traced from Morton County across Burleigh and Kidder Counties and into Stutsman County. The Grand River system (Flint, 1955) in South Dakota has several upper branches in Sioux, Emmons, Logan, and McIntosh Counties in North Dakota. According to previous workers these three major ancestral river systems eventually flowed eastward and northward toward Hudson Bay. This study supports that conclusion.

The diversion and Wisconsin meltwater drainage of south-central North Dakota (pl. 8) comprises two major diversions of the Missouri River and numerous meltwater channels. The ice-marginal or diversion drainage roughly parallels the limit of glaciation. The first major diversion in a channel cut in bedrock extends from the Knife River through Elm Creek Valley, southeastward and into Big Muddy Creek Valley. Initially this water then flowed through the Strasburg Channel system. Later the water flowed through the Porcupine Creek Channel system when the ice front covered the Strasburg Channel and filled it with till. In the second major diversion along the present course of the Missouri River, Wisconsin meltwater flowed into the Missouri River through the following channels: Turtle Creek, Painted Woods Creek, Burnt Creek, Apple Creek, Heart River, Random Creek, Glencoe, Cannonball River, Badger Creek, Clear Creek, and Beaver Creek Channels.

ANCESTRAL KNIFE RIVER SYSTEM

The ancestral Knife River system as shown on plate 7 includes the present Knife River and the following channels: Knife River, Painted Woods Creek, Garrison, and Snake Creek Channels. A major preglacial drainage divide in Oliver, Burleigh, and Kidder Counties separated this drainage system from the ancestral Cannonball River system to the south. The course of the east flowing ancestral Knife River changes abruptly northward as it passes through the bedrock escarpment of the Missouri Plateau at Lincoln Valley in Sheridan County.

Painted Woods Creek Channel. – In northwestern Burleigh County the only channel of the ancestral Knife River system is here referred to as the Painted Woods Creek Channel. Topographically, it is a meltwater channel which ranges from about a quarter of a mile to two miles wide and contains valley outwash. The floodplain is about 110 feet below adjacent high ground. Test hole data show that the channel contains a thin fill of outwash and till ranging in thickness from 20 to 66 feet. The valley of Painted Woods Creek is a small part of a broad bedrock swale in northern Burleigh County (pl. 3), in the Cannonball Formation. Painted Woods Creek Channel probably consisted of two minor tributary segments of the ancestral Knife River (pls. 3 and 7). The valley of Painted Woods Creek was a Wisconsin meltwater channel (pl. 8).

ANCESTRAL CANNONBALL RIVER SYSTEM

The ancestral Cannonball River System as shown on plate 7 includes the Cannonball River, Heart River, Little Heart River, Sweetbriar Creek, and Square Butte Creek, and the following channels: Badger Creek, Apple Creek, Random Creek, Glencoe, Heart River, Sibley Butte, Rice Lake, Cannonball River, Big Muddy Creek, Logan, and Wing. A major preglacial drainage divide in Sioux, Emmons, and Logan Counties separated this drainage system from the ancestral Grand River system (pl. 7). The ancestral Cannonball River flowed northeastward from Sioux and Grant Counties across Burleigh and Kidder Counties into Stutsman County.

Badger Creek Channel. – A large abandoned valley occupied in part by the underfit Badger Creek is here named Badger Creek Channel. The valley can be traced from the Missouri River, across the northwestern corner of Emmons County, and into southeastern Burleigh County, with a small segment southwest of Long Lake. The valley walls have from 200 to 300 feet of local relief. The valley fill consists mostly of lake sediments and outwash deposits with minor surficial alluvium. Dune sand occurs along the Burleigh-Emmons County line. Test hole data indicates a thick valley fill (pl. 4, cross-section, $A-A^1$), ranging in thickness from 30 to 179 feet. The bedrock valley floor in the Long Lake area is the Cretaceous Pierre Formation, and the valley walls are cut into the Cretaceous Fox Hills Formation. In Emmons County the bedrock valley floor and walls are both cut in the Fox Hills Formation. Badger Creek Channel probably was a segment of the main channel of the ancestral Cannonball River. During the Wisconsin, Badger Creek

Channel was a significant meltwater channel from Glacial Long Lake (pl. 8).

Glencoe Channel. — A large abandoned valley which has poorly developed surface drainage is here named Glencoe Channel. It extends from the northwestern corner of Emmons County northward to McKenzie Slough in south-central Burleigh County. The valley floor is about 100 feet below adjacent high ground. The valley fill consists mostly of lake sediments and outwash deposits with minor surficial alluvium. Dune sand and other wind blown deposits are common in the central and lower valley. Test hole data has shown a thick valley fill of outwash composed mostly of sand and gravel but also much silt and clay, ranging in thickness from 57 to 221 feet. It is commonly over 175 feet thick. The valley, in its deepest part, is cut into the Cretaceous Fox Hills Formation and the adjacent valley walls are Hell Creek. Glencoe Channel probably was a tributary of the ancestral Heart River. During the Wisconsin, Glencoe Channel was a significant meltwater channel draining into Glacial Lake McKenzie.

Heart River Channel. — In the southern part of Burleigh County several valleys which are occupied in part by Apple, Random, and Long Lake Creeks are here referred to as the Heart River Channel. Some of the valleys are abandoned and have poorly developed surface drainage. In the McKenzie Slough area the exact position of the Heart River channel is obscured by the overlying lake plain. This channel can be traced from the present mouth of the Heart River in Morton County eastward toward McKenzie in Apple Creek valley and southeastward to Long Lake at Moffit (pl. 4, cross-section J-J[1]). In the Lake McKenzie Basin, test hole data indicate that the ancestral Heart River had two separate channels. The western channel is associated with the Glencoe tributary (pl. 7). The valley floor is about 100 feet below the adjacent high ground except in Lake McKenzie Basin which is a plain of low relief. The valley fill consists mostly of lake sediments and outwash deposits with minor floodplain alluvium along present streams. Test hole data reveal thick valley fill (pl. 4, cross-sections H-H[1] and D-D[1] composed mostly of clay and silt with variable amounts of sand and gravel. The fill ranges in thickness from 105 to 245 feet, but it is generally about 150 to 200 feet thick. The bedrock valley is cut into the Cretaceous Fox Hills Formation in the Lake McKenzie Basin area and into the Hell Creek Formation to the west. The Heart River Channel probably was a segment of the main channel used by the ancestral Heart River from Morton County to its former junction at Long Lake with the ancestral Cannonball River.

Apple Creek Channel. — In the central part of Burleigh County the bedrock valley of Apple Creek coincides with much of its present valley and is here named Apple Creek Channel. The channel begins in a broad bedrock valley of Lake McKenzie Basin and narrows quickly upstream along the branches of Apple Creek. The floodplain is about 200 feet below the adjacent high ground. Test hole data indicate a valley fill of outwash and alluvium ranging in thickness from 23 to 71 feet. The valley is cut into the Hell Creek and Cannonball Formations. Apple Creek Channel probably was a minor tributary of the ancestral Heart River but part of the configuration of its bedrock valley can be attributed to cutting by Wisconsin meltwater. The ancestral Heart River drainage was well-developed in the West Branch of Apple Creek, but the East Branch was a shorter tributary. The present upper part of East Branch formerly drained through Rice Lake Channel, but during the Wisconsin the direction of flow was reversed (pls. 7 and 8).

Random Creek Channel. – South of Sterling in Burleigh County a meltwater channel containing outwash and presently occupied by Random Creek is here named Random Creek Channel. The maximum local relief of the valley walls is about 150 feet where it cuts the Long Lake end moraine. Test hole data show that the valley fill is thick near its junction with the Heart River Channel in the Lake McKenzie Basin, but it thins markedly eastward from 127 feet to as little as 5 feet thick. The valley is cut into the Hell Creek Formation. Random Creek Channel probably was a minor tributary of the ancestral Heart River. During the Wisconsin, Random Creek Channel was a significant meltwater channel (pl. 8).

Cannonball River Channel. – A channel can be traced from its junction with the Heart River and Badger Creek Channels at Long Lake in Burleigh County, northeastward across Kidder County into Stutsman County, and is here referred to as the Cannonball River Channel. Topographically, it initially appears as an abandoned valley occupied by Long Lake, followed by a chain of kettles, until it finally loses its topographic expression where it passes beneath the drift in the Missouri Coteau district. The valley floor is about 100 feet below adjacent high ground. Test hole data have shown that the valley fill is from 124 to 168 feet thick (pl. 4, cross-section B-B^1). In Kidder County, Rau, and others (1962, p. 37) reported valley fill up to 300 feet thick. The bedrock valley floor is cut into the Cretaceous Pierre Formation and the adjacent walls are cut into the Fox Hills Formation. The Cannonball River Channel probably was the former main channel of the ancestral Cannonball River. During the Wisconsin, part of the Cannonball River Channel was a significant spillway.

Sibley Butte Channel. – A channel in western Kidder County curves across the county line into Burleigh and is here named Sibley Butte Channel. Topographically, it is a partly buried valley filled with till, with local relief from about 35 to 100 feet. In Burleigh County test hole data indicate valley fill ranging in thickness from 136 to 184 feet, composed of till, sand, and gravel. The valley is cut into the Fox Hills and Hell Creek Formations. Sibley Butte Channel, probably a tributary of the ancestral Cannonball River, was filled with drift during the Wisconsin.

Rice Lake Channel. — A short channel extending from eastern Burleigh County into Kidder County is here named the Rice Lake Channel. It comprises an upper part of the East Branch of Apple Creek, an outwash channel, and a buried channel beneath the Long Lake moraine. The local relief varies from about 50 to 100 feet. According to test hole data the valley fill of till, sand, and gravel, ranges from 74 to 105 feet thick. The valley is cut into the Hell Creek and Cannonball Formations. Rice Lake Channel probably was a tributary of the Sibley Butte Channel of the ancestral Cannonball River system. During the Wisconsin, Rice Lake Channel was partly filled with drift.

Wing Channel. — A channel can be traced from eastern Kidder County to northeastern Burleigh County and is here referred to as the Wing Channel. The Wing Channel in Burleigh County comprises at least three kettle chains. The local relief is about 100 feet. The valley fill of till, sand, and gravel, ranges from 112 to 197 feet thick as shown by test drilling. The bedrock valley is cut into the Hell Creek and Cannonball Formations. The preexisting Wing River drainage probably was a tributary of the ancestral Cannonball River. During the Wisconsin, the Wing Channel was filled with drift.

Little Heart River Channel. — South of Bismarck a short buried channel can be traced beneath the outwash and alluvial terraces and is here named the Little Heart River Channel (pls. 3 and 7). The valley fill is mostly sand and gravel about 125 to 170 feet thick.

ANCESTRAL GRAND RIVER SYSTEM

The ancestral Grand River system shown on plate 7 includes the Grand River, Porcupine Creek, Beaver Creek, Sand Creek, Clear Creek, Cattail Creek, Little Beaver Creek, and Strasburg Channel. The ancestral Grand River can be traced from Logan, McIntosh, Emmons, and Sioux Counties in North Dakota into the ancestral Cheyenne River in north-central South Dakota.

Synthesis of Drainage History

The preglacial and pre-Wisconsin river systems of south-central North Dakota included the ancestral Knife River, Cannonball River, and Grand River systems. These three river systems flowed east on the Missouri Plateau slope, through the Missouri Plateau escarpment, and north into Hudson Bay.

During glaciation as the ice sheet encountered these rivers it blocked them, ponding water in the channels. With further glacial encroachment these drainage systems became partly to completely filled with drift and the direction of the drainage was reversed as the channels carried meltwater away from the ablating glacier. Interfluves across preglacial and pre-Wisconsin drainage divides were cut by the diverted meltwater. The new drainage took a southerly course near the outer glacial margin.

The ancestral Missouri River was initially diverted through the valleys of Elm Creek and Big Muddy Creek and through the Strasburg Channel system. When the glacier advanced and buried the Strasburg Channel, the water flowed through the Porcupine Creek Channel system. The second major diversion of the Missouri River along its present course is nearer the Wisconsin morainal belt in the Missouri Coteau district. Wisconsin meltwater flowed into the diverted Missouri River through numerous channels in the Coteau Slope district.

SYNTHESIS OF PLEISTOCENE HISTORY

Pre-Wisconsin Ages

No evidence for glaciation older than the Wisconsin Age was found in Burleigh County. Since the limit of glaciation in south-central North Dakota is some distance west and southwest of Burleigh County (pl. 8), it is conceivable that at least one earlier glacier spread over this area but evidence is lacking to establish which glaciation occurred.

The preglacial and pre-Wisconsin drainage in Burleigh County consisted of the ancestral Knife River system and the ancestral Cannonball River system (pl. 7). The drainage flowed east and north into Hudson Bay cutting many deep channels into bedrock.

Wisconsin Age

Wisconsin Age ice advanced four times into Burleigh County. The Napoleon advance was the first followed by the Long Lake, Burnstad, and Streeter advances. Except for the Burnstad Drift, radiocarbon dating of these advances in Burleigh County is yet to be established, but it is assumed they are equivalent to the sequence of glacial advances in Logan and McIntosh Counties where several radiocarbon dates have been determined.

The Wisconsin drainage in Burleigh County consisted of the Missouri River and various meltwater channels (pl. 8). The meltwater streams reoccupied many of the preexisting channels but the stream flow was in the opposite direction from that of the preglacial drainage. The integrated Wisconsin drainage flowed to the south. Many of the preexisting channels became partly filled with glaciolacustrine and glaciofluvial sediments.

NAPOLEON GLACIAL ADVANCE

During the Wisconsin glaciation the Napoleon glacier advanced across Burleigh County and deposited sheet moraine upon a stream-eroded bedrock topography (fig. 22) probably over 38,000 years ago, but perhaps as recently as 28,700 years ago. By this time the ancestral Missouri River had been diverted and carried melt-water from the ablating Napoleon ice. The meltwater flowed through the Heart River, Glencoe, and Badger Creek Channels which were being partly filled with outwash. The Napoleon advance probably didn't continue for an extended period as suggested by the uniformly thin till and by the lack of constructional features such as end moraines.

Following the Napoleon advance was a period of glacial recession and erosion in Burleigh County. Clayton (1962, p. 70) assumed that this period lasted over 25,000 years, but in Burleigh County the Napoleon till is not extensively eroded or weathered, and in many respects is quite similar lithostratigraphically to Long Lake and Burnstad tills, so it may not have lasted that long. Locally where drainage is well-developed, much of the Napoleon till has been eroded, but part of this erosion is postglacial.

LONG LAKE GLACIAL ADVANCE

The Long Lake glacier advanced into eastern and northern Burleigh County about 12,000 to 13,000 years ago (fig. 23). End moraine was deposited in the eastern part of the county, and as the ice receded it became more lobate and formed three distinct loops of end moraine. The moraine in the northern part of the county was later overridden by the Burnstad advance.

Meltwater from the ablating Long Lake ice flowed through the Burnt Creek, Apple Creek, Heart River, and Badger Creek Channels partly filling them with outwash. Outwash was also being transported to the Missouri River and to the newly formed Glacial Lake McKenzie. This proglacial lake formed on the distal side of the south and middle lobes of ice. Spillways from the lake drained through the Heart River, Glencoe, and Badger Creek Channels. Glacial Lake McKenzie could have been formed, in part, by the damming of the Missouri River as the Zeeland glacier advanced over the Strasburg Channel in Emmons County. The ponding probably was caused partly by the filling of the spillways with outwash.

The Long Lake glacial advance probably lasted only a short period of time.

BURNSTAD GLACIAL ADVANCE

The Burnstad glacier advanced into northern Burleigh County about 12,000 years ago (fig. 24). The glacier overrode the moraine deposited by the Long Lake glacier in the northern part of the county, and truncated the north loop of the end moraine. The margin of the Burnstad glacier stagnated forming dead-ice moraine.

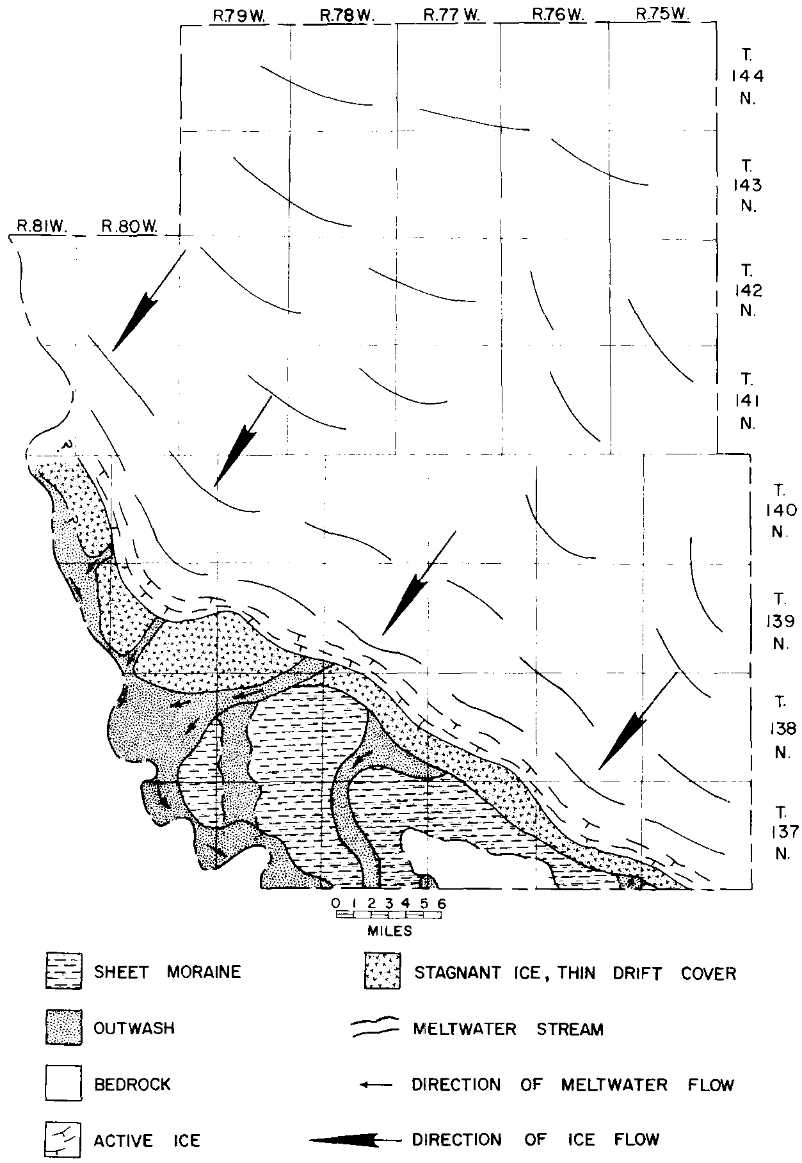

Figure 22. Napoleon glacial advance with the deposition of sheet moraine.

Meltwater from the ablating Burnstad ice flowed through Apple Creek, Random Creek, and Cannonball River Channels

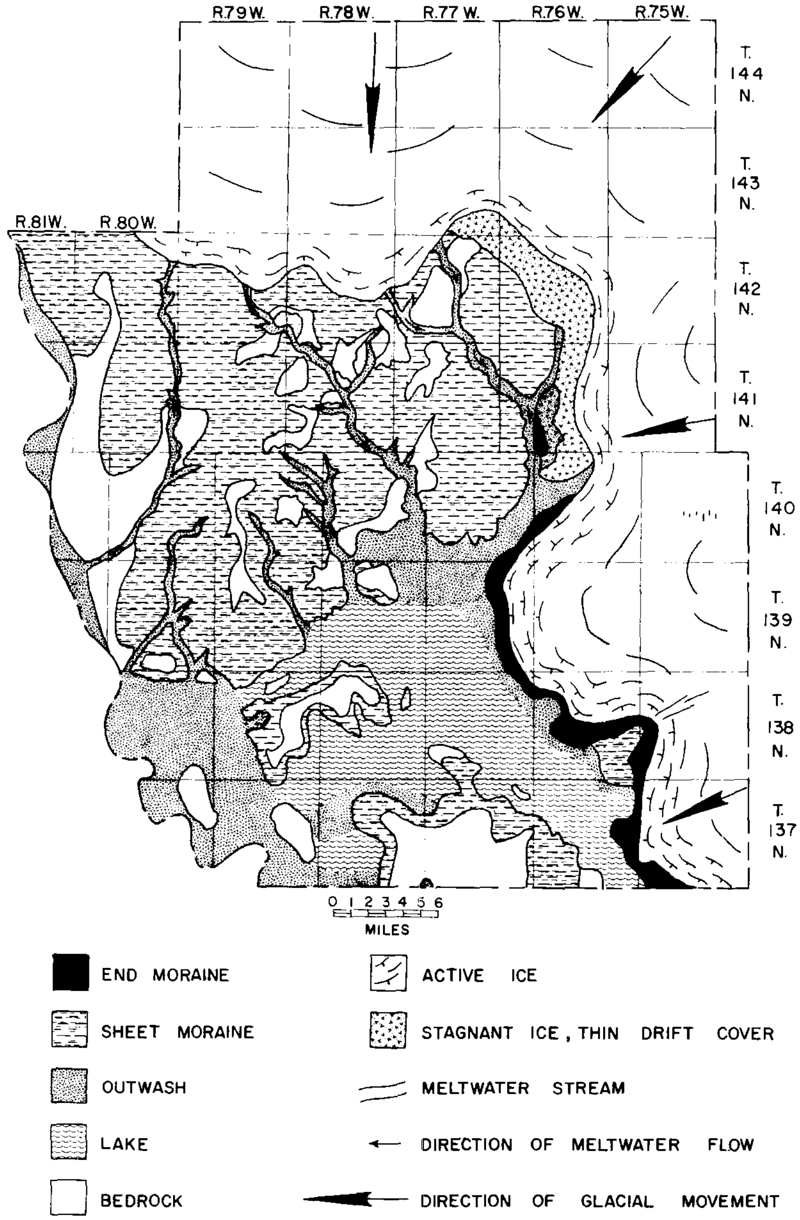

Figure 23. Long Lake glacial advance with the deposition of the Long Lake end moraine and the McKenzie lake plain.

into Glacial Lake McKenzie. Outwash transported by the meltwater formed an outwash plain in the northern part of Lake McKenzie. Cutting and filling on the floodplain of the Missouri River perhaps formed the higher terraces at this time.

Wind erosion and deposition in southwestern Burleigh County formed sand dunes along the south Lake McKenzie Basin and along the Missouri River Trench. Most of the sand was derived from outwash.

All that remained of the Burnstad ice sheet was a stagnant remnant, covered with drift, as the Streeter glacier advanced.

STREETER GLACIAL ADVANCE

The Streeter glacier advanced into northern Burleigh County about 12,000 years ago (fig. 25). A number of end moraine loops were deposited along its lobate ice front and a small portion of one loop of the Streeter end moraine is in T. 144 N., Rs. 76 and 77 W., on the northern border of Burleigh County.

Meltwater from the ablating Streeter ice flowed through Painted Woods Creek and Badger Creek Channels into the Missouri River and through Apple Creek, Random Creek, and Cannonball River Channels into Glacial Lake McKenzie. Outwash was deposited in the meltwater channels on the distal side of the end moraine and also on the stagnant Burnstad ice. The outwash on Burnstad ice collapsed when the ice melted. Cutting and filling in the Missouri River floodplain continued to modify the terraces.

Sand dunes were built up by wind erosion and deposition in southeastern Burleigh County.

Slow melting of the drift-covered Burnstad ice continued following the Streeter advance. Clayton (1962, p. 68) states that the Burnstad ice continued to melt for over 2,000 years; the resulting deposits of dead-ice moraine were slowly assuming their present surface expression during that time.

Recent Age

The final phase of the Pleistocene history, the Recent, began about 5,000 years ago and continues to the present. During this period much of the Coteau Slope was modified by stream erosion and slope wash, and the present drainage pattern was established. Numerous kettles and other depressions on the Missouri Coteau caught surface water and were partially filled with slope wash sediments. The sand dunes have been intermittently active, reflecting wet and dry climatic cycles.

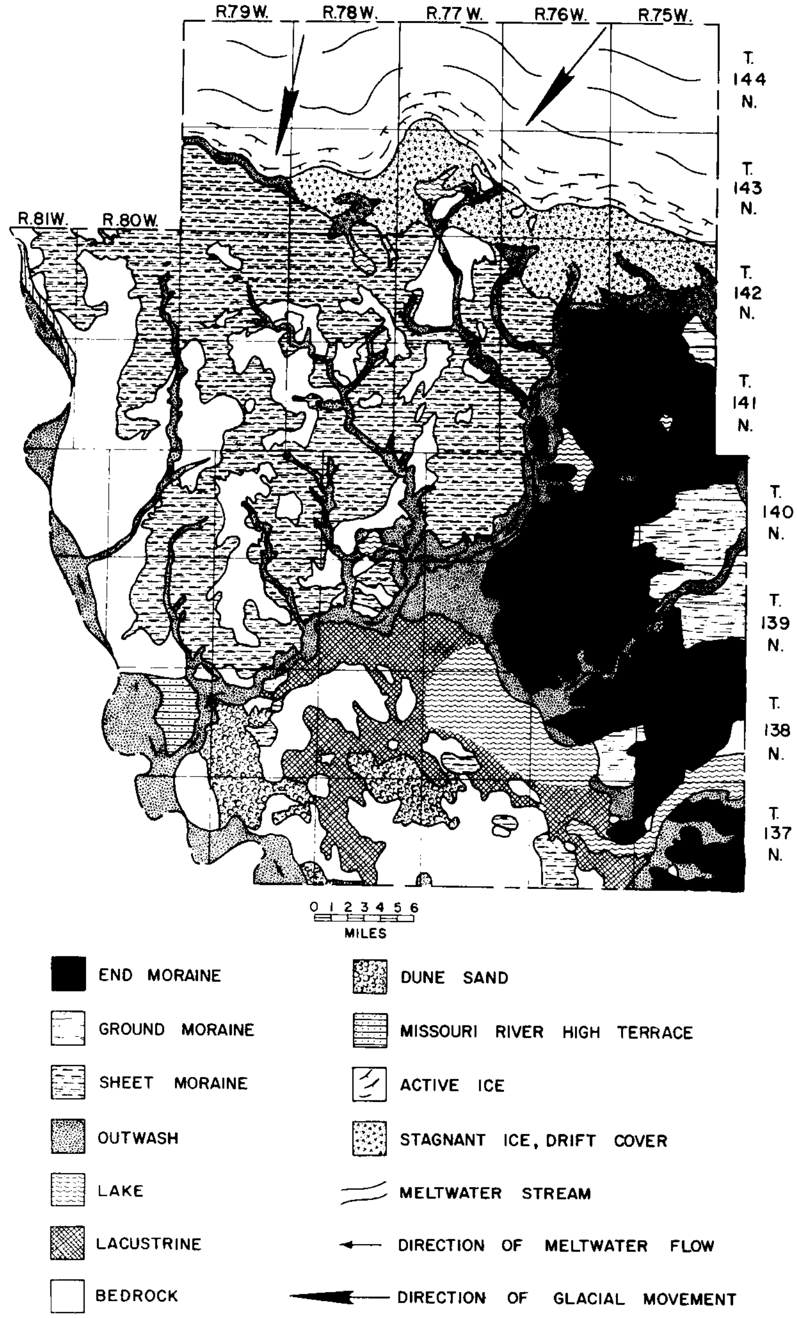

Figure 24. Burnstad glacial advance with the truncation of the Long Lake end moraine and the stagnation of Burnstad glacial ice.

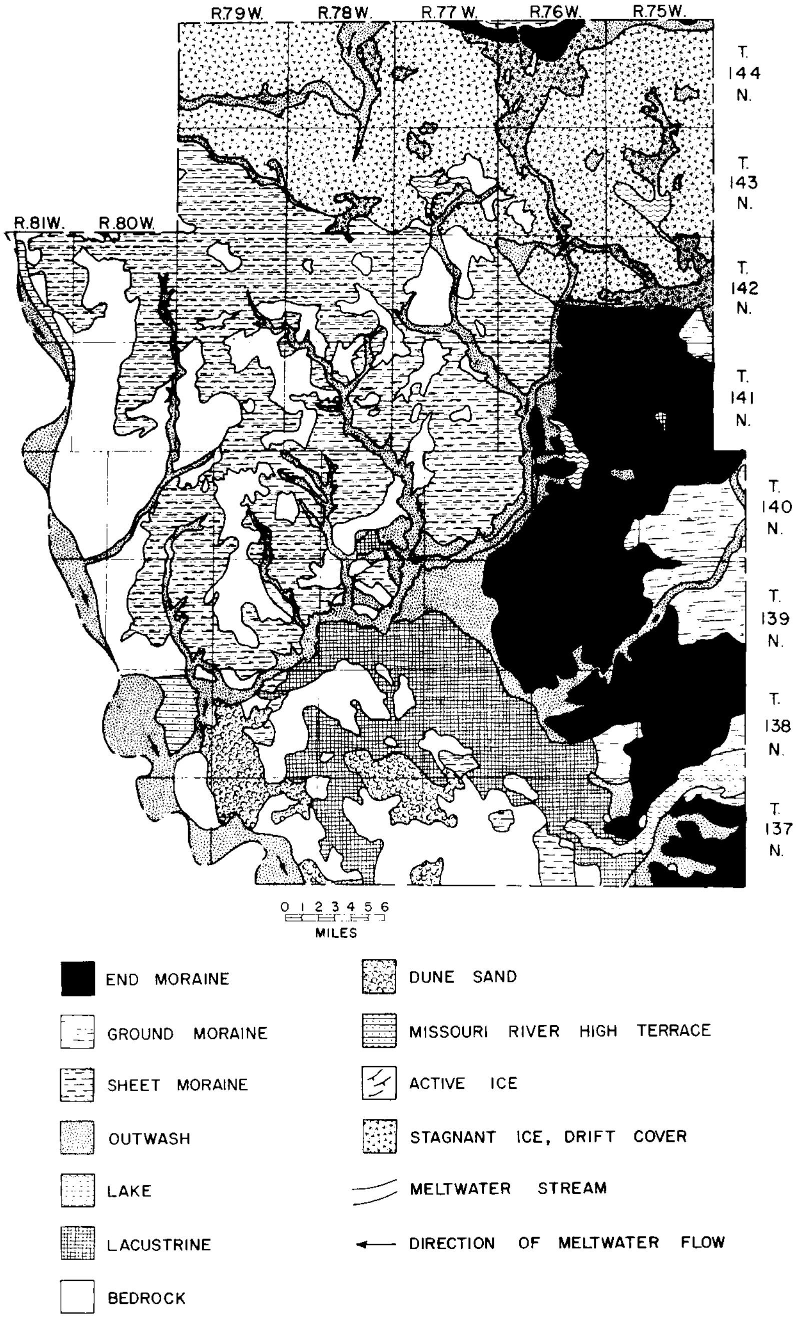

Figure 25. Streeter glacial advance with the deposition of the Streeter end moraine and Burnstad dead-ice moraine.

ECONOMIC GEOLOGY

PETROLEUM

Fourteen petroleum exploratory wells have been drilled in Burleigh County since 1949. Five of the wells were drilled to the granite basement, seven wells were drilled to the Deadwood Formation, and two were drilled to the Madison Group. Summaries, providing lithologic descriptions of seven of these wells have been published (Caldwell, 1953a, 1953b, 1954; Smith, 1954; George, 1957; Eisenhard, 1958; Mendoza, 1959).

A slight show of oil was reported from the Winnipeg Formation sandstone at a depth of 6576-6629 feet in the Continental Oil Company-Duemeland No. 1 well (sec. 3, T. 140 N., R. 77 W.), but there has been no oil production in the county.

LIGNITE

Lignite from the Tongue River Formation is the second most valuable mineral in Burleigh County (Mullen, 1963, p. 806). Lignite in the underlying Ludlow and Hell Creek Formations is generally too thin to mine economically. Test hole 1985 at Wilton and test hole 1990 at Regan penetrated several lignite beds in the Tongue River Formation. At the Wilton test hole the first lignite bed is at a depth of 22 to 26 feet below the surface. This seam crops out in the Wilton area, and its areal extent is probably quite small. The second, the Wilton bed at a depth of 59 to 65 feet, contains three feet of interbedded shale. The third seam is only one foot thick at a depth of 106 feet. The fourth lignite bed at a depth of 138 feet, is one foot thick underlain by six feet of silt and lignitic material. This seven foot unit about 73 feet below the Wilton bed apparently is equivalent to a commercial lignite bed that was mined in the Wilton area. The fifth lignite bed at a depth of 163 feet, is one foot thick underlain by two feet of lignitic sand. This unit appears to be equivalent to the Fairman bed, another commercial lignite bed in Burleigh County. In test hole 1985 it is underlain by the "basal sandstone" unit of the Tongue River Formation. In T. 143 N., R. 81 W. where Brant (1953) reported a Fairman bed outcrop, it appears that only the lowermost part of the Tongue River Formation is present so it is assumed that this lignite is equivalent to the Fairman bed. At test hole 1990, near Regan, only the lower two lignite beds were present, each one foot thick. In test hole 1990 the fifth, or Fairman bed, is 66 feet above the Cannonball Formation contact, but in the Wilton test hole it is 56 feet above the same contact (see pl. 4, cross-section G-G^1).

During 1961, as reported by the State Coal Mine Inspector (Easton, 1961), Burleigh County had only one operating lignite mine. It was the Ecklund-Taplin strip mine near Wilton which produced 13,084 tons of lignite. During the summer of 1962 the same company operated a strip mine in sec. 8, T. 142 N., R. 79 W.

CONSTRUCTIONAL MATERIALS

Sand and gravel. — In 1962 Burleigh County ranked sixth in the State in sand and gravel production (Mullen, 1963, p. 806). Sand and gravel presently ranks as the most valuable mineral in the county. It is used for building, paving and fill. The best possibilities for commercial production are the terraces along the Missouri River, outwash deposits, and kames. The locations of the gravel pits in Burleigh County are shown on plate 1. The terraces south of Bismarck contain two of the largest pits in Burleigh County. Test holes in the terraces reveal a thickness of about 100 feet of sand and gravel, but this area is more valuable as a source of ground water than as gravel pits. Much of the gravel in the county contains shale in amounts which are detrimental for concrete.

Clinker. — Burleigh County has a minor amount of clinker or scoria, a material formed by burning lignite beds which baked the overlying sediments. Clinker is used mostly for road metal. A clinker pit is in SW 1/4 SE 1/4 sec. 4, T. 142 N., R. 79 W.

Riprap and building stone.—Abundant glacial erratic boulders, which may be used as riprap, are found in Burleigh County. Riprap and building stone can also be obtained from the Tongue River Formation which contains beds of resistant sandstone, conglomeratic sandstone, and sandy limestone. It is not of high quality, but it has been used locally as a decorative building stone, mainly for retaining walls, gardens, and patios.

Clay. — Clay deposits are abundant in Burleigh County in glacial deposits as well as in the Tongue River and Cannonball Formations. There are no commerical clay operations in Burleigh County, but there is a light weight aggregate plant in Morton County west of Mandan using Cannonball Formation clay.

SURFACE WATER

Much of the surface water in Burleigh County is in numerous undrained depressions, intermittent streams, and a few permanent lakes. The largest source is the Missouri River which provides the muncipal water supply for Bismarck and is also used for irrigation.

GROUND WATER

Ground water is abundant in Burleigh County. Aquifers are found in the sands and gravels in the Missouri River terraces and the buried drainage channels (pls. 7 and 8). Smaller aquifers are found in the sandstones and sands of the Fox Hills, Hell Creek, Cannonball, and Tongue River Formations. The sandstones of the Fox Hills Formation and basal sandstone unit of the Tongue River Formation probably contain the best bedrock aquifers. In Burleigh County quantity is generally not a problem, but the chemical quality is not satisfactory for all uses. The ground water is generally acceptable for stock-watering, but locally it may not be satisfactory for irrigation. Several chemical analyses of irrigation water show a salinity, sodium, and residual sodium carbonate hazard. Some of this water may be safely used for irrigation, even though it may rate poorly according to some quality standards. Ground water irrigation is being conducted on the river terraces south of Bismarck and on the lake plain southeast of McKenzie.

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APPENDIX A

DETAILED DESCRIPTIONS OF SURFACE SECTIONS

SECTION 1-62 SW 1/4 SW 1/4 sec. 35, T. 137 N., R. 77 W.
Moffit Southwest Section 1
0.2 mi. east of road, west side of bluff.

Cretaceous – Hell Creek Formation	Feet	Inches
8. Sandstone, as in unit 4, friable, massive.	2	9
7. Claystone, sandy to very sandy, lenses of sand (as in unit 4), light olive gray, scattered iron staining.	4	0
6. Sandstone and sand, friable, as in unit 4 interbedded shale, light olive gray, flaky, very lenticular bedding, sand similar to unit 4.	4	10
5. Shale, light olive gray, sandy, contains plant fragments.	0	3
4. Sandstone, yellowish-gray (5Y7/2) to light brown (5YR5/6) due to iron staining and oxidation, fine-grained ironstone concretions (one measured 6 in. thick, 30 in. long), friable, non-calcareous, minor shale and claystone interbedded.	1	0
3. Shale, light olive gray to olive gray (5YR3/2), numerous carbonaceous and woody fragments, fissile to blocky, macerated plant fragments.	6	10
2. Coal, dark gray (N3), woody structure, lenticular.	0	9
1. Shale, light olive gray (5Y5/2) blocky, compact.	4	9
Total	25	2

SECTION 2-62 SW 1/4 NW 1/4 sec. 35, T. 137 N., R. 77 W.
Moffit Southwest Section 2
East roadcut, 0.4 mi. south of sec. corner.

Cretaceous – Hell Creek Formation	Feet	Inches
4. Sandstone, moderate yellowish-brown, fine to very fine-grained, massive; sandstone, dusky yellow (5Y6/4), friable, fine to very fine-grained.	10	10
3. Sandstone and sand, moderate yellowish-brown (10YR5/4) to light brown (where iron stained), fine to very fine-grained, abundant ironstone concretions and fragments, occa-		

sional streaks of carbonaceous material and plant fragments, mica flakes.	4	10
2. Shaly sandstone, friable, light olive gray, light brown (5YR5/6) and grayish-orange (10YR-7/4) where oxidized and iron stained, fine to very fine-grained, numerous plant fragments and stems, round ironstone concretions (sandy), increasing shale content toward upper part of unit.	4	0
1. Claystone or mudstone, light olive gray, (5Y5/2), very sandy, weathers light gray (N7), numerous ironstone fragments; sand, fine to very fine-grained.	8	10
Total	28	6

SECTION 3-62 SW 1/4 SE 1/4 sec. 11, T. 137 N., R. 76 W.
Long Lake Section
North roadcut, measured from base of hill.

	Feet	Inches
Pleistocene – Long Lake Drift		
6. Till, olive gray (5Y 4/1), clayey and silty, abundant stones (sand to boulder size), mostly limestone and igneous rocks, calcareous.	5	0
Cretaceous – Fox Hills Formation		
5. Sandstone, as in unit 1, abundant indurated sandstone weathering into a flaggy (1-2 in.) rubble.	7	0
4. Sandstone, as in unit 1, friable, massively bedded.	5	0
3. Sandstone, as in unit 1, abundant ironstone concretions, thinly bedded, indurated, noncalcareous.	1	8
2. Sandstone, as in unit 1, except lack of fractures filled with calcareous material, very thinly bedded (1 mm), abundant black carbonaceous and ferruginous material along some bedding planes.	3	2
1. Sandstone, light olive gray (5Y 5/2) to pale olive (10Y 6/2), weathering to yellowish-gray (5Y 7/2), friable except for numerous ironstone concretions and indurated beds, noncalcareous, fine to very fine-grained, numerous dark mineral grains, common fractures filled with calcareous material, thinly bedded (1/4 to 1 in.), some cross-bedding.	14	6
Total	36	4

SECTION 4-62 NW 1/4 NW 1/4 sec. 16, T. 138 N., R. 75 W.
Long Lake Moraine Section

Pleistocene — Ice-contact lacustrine	Feet	Inches
1. Clay, light olive gray (5Y 5/2) and olive gray (5Y 3/2), silty, calcareous, blocky to flaky, weathers yellowish-gray (5Y 7/2), abundant plant material.	14	6

SECTION 5-62 SE corner NW 1/4 sec. 13, T. 140 N., R. 81 W.
Riverview School No. 1 Section.
West roadcut, measured from base of knoll.

Tertiary — Tongue River Formation ("basal sandstone")	Feet	Inches
7. Sandstone and sand, grayish-olive (10Y 4/2), weathering grayish-orange (10Y 7/4) to dark yellowish-orange (10YR 6/6), strongly cross-bedded, medium to fine-grained, few interbedded lenses of fine to very fine-grained sand, non-calcareous except when cemented with calcite or ferruginous material.	14	6

Tertiary — Cannonball Formation.	Feet	Inches
6. Shale and siltstone, as in unit 4, contact appears disconformable (excellent exposure).	8	10
5. Limestone, pale yellowish-brown (10YR 6/2) argillaceous and silty, lenticular.	0	1
4. Shale and siltstone, interbedded. Shale, dark yellowish-brown, (10YR 4/2), silty, numerous olive black plant and other carbonaceous fragments, non-calcareous, blocky, thinly to fissile bedding, compact. Siltstone, dark yellowish-brown, shaly, sandy, non-calcareous, blocky. Shale olive black (5Y 2/1), fissile and blocky, minor amount.	5	4
3. Siltstone, as in unit 1, interbedded with sandstone, friable as in unit 2.	0	6
2. Sandstone, light olive gray (5Y 5/2), friable, very silty, very thinly bedded to laminated (1-3mm), non-calcareous, very fine-grained.	0	7
1. Siltstone, dusky yellow (5Y 6/4) weathering yellowish-gray (5Y 7/2), thinly (2-5mm) to laminated bedding, non-calcareous, blocky.	1	8
Total	31	6

SECTION 6-62 NE 1/4 NW 1/4 sec. 13, T. 140 N., R. 81 W. West roadcut, 1180 feet north of Section 5-62 Stratigraphically 51 feet 8 inches above Cannonball Formation contact.

Tertiary – Tongue River Formation	Feet	Inches
10. Sandstone and sand, dusky yellow, weather grayish-yellow, very fine-grained, minor fine-grained, cross-bedded, calcareous, numerous ironstone concretions, local lenticular shale conglomerate.	15	10
9. Conglomerate, shale pebbles and rounded fragments, light olive gray (5Y 5/2); sand matrix, dusky yellow (5Y 6/4), very fine and fine-grained, calcareous; sandstone, dusky yellow, very fine-grained, calcareous.	15	9
8. Sandstone and sand of intervening unit between Sections 6-62 and 5-62.	1	6
Total	33	1

Intervening unit between Sections 6-62 and 5-62	Feet	Inches
8. Sandstone and sand, yellowish-gray (5Y 7/2) weathering yellowish-gray (5Y 8/1), friable, fine to very fine-grained, scattered shale pebbles, lenticular shale pebbles (appear to be reworked Cannonball Formation), cross-bedded.	27	6
7. Sandstone, as in unit 7 of Section 5-62, petrified tree log (32 in. long, 10 in. diameter), friable, cross-bedded.	9	8
Total	37	2

SECTION 7-62 SW corner sec. 1, T. 140 N., R. 81 W. Coal Butte Section West cut, north-south section-line road.

Tertiary – Tongue River Formation	Feet	Inches
8. Covered interval, slope wash.	10	0
7. Shale, dark yellowish-orange, calcareous, weathers grayish-yellow, compact.	0	11
6. Siltstone, light gray (N 7), friable, very fine-grained sand, calcareous, massive.	3	11
5. Claystone, dark yellowish-orange (10YR 6/6), indurated, calcareous, ferruginous, resistant, occurs in thin beds (up to 3 in. thick); interbedded shale, dusky yellow, compact, calcareous, weathers grayish-yellow.	5	10
4. Shale, carbonaceous, brownish-black (5YR 2/1), abundant plant material, non-calcareous.	0	2
3. Shale, dusky yellow (5Y6/4), compact, weathers yellowish-gray (5Y7/2), non-calcareous.	1	2

2. Shale, pale yellowish-brown (10YR6/2), fissile, abundant brown carbonaceous material, non-calcareous.	0	6
1. Shale, carbonaceous and thin seams (1 in.) of lignite coal; shale, brownish-black (5YR2/1) carbonaceous, blocky, non-calcareous, weathers medium light gray (N6).	1	9
Total	24	3

SECTION 8-62 SW 1/4 NE 1/4 sec. 31, T. 139 N., R. 80 W.
Northern Pacific Railway Section
South railcut, east of bridge.

Pleistocene – Drift	Feet	Inches
10. Sand, yellowish-gray (5Y7/2), very fine-grained, silty, calcareous, igneous pebbles and boulders on bedrock contact.	20	0
Tertiary – Cannonball Formation		
9. Siltstone, olive gray, sandy, non-calcareous, lenticular, dusky yellow (5Y6/4) sand, very fine-grained, moderate brown (5YR4/4) ferruginous coating.	13	6
8. Siltstone, light olive gray (5Y6/1), compact shaly, fissile to flaky, non-calcareous.	10	10
7. Siltstone, dark gray, olive black, brownish-black, (5YR2/1) interbedded, shaly, fissile to flaky, soft, non-calcareous.	16	5
6. Shale, dark gray (N3), flaky to fissile, non-calcareous, soft.	0	7
5. Claystone concretions, dark yellowish-orange (10YR6/6) and light brown (5YR5/6), tube-like forms and pebble size; sandstone matrix, olive gray, friable, fine to very fine-grained, silty, clayey.	1	1
4. Siltstone, olive gray and olive black, slightly calcareous, flaky and fissile, weathers light olive gray.	7	3
3. Sandstone, light bluish-gray (5B7/1) weathers light gray (N7), friable except where locally indurated with calcareous cement, abundant dark grains.	4	0
2. Sandstone, light olive gray (5Y5/2), friable, non-calcareous, very thinly bedded; siltstone, as in unit 1.	2	1
1. Siltstone, olive gray (5Y3/2), olive black (5Y2/1), interbedded, flaky, soft, non-calcareous.	2	9
Total	78	6

SECTION 9-62 SW 1/4 SE 1/4 sec. 26, T. 138 N., R. 80 W.
Apple Creek Section
South bank, northwest side of bluff.

Tertiary — Ludlow Formation	Feet	Inches
12. Shale and siltstone, olive gray and dusky yellow, fissile to compact, flaky, non-calcareous, ferruginous ironstone concretions.	8	10
11. Shale, brownish-black, brownish-gray, and grayish-black (N2), fissile, carbonaceous, in part lenticular lignite beds; interbedded sandstone, yellowish-gray (5Y7/2), friable very fine-grained, ferruginous concretions.	8	5
10. Sandstone, dusky yellow and brownish-gray (5YR4/1), friable, very thinly bedded (1-2mm), carbonaceous, shale partings, non-calcareous, very fine-grained, silty, ferruginous concretions.	3	5
Cretaceous — Hell Creek Formation		
9. Shale, olive black (5Y2/1), olive gray, fissile to flaky, non-calcareous, silty.	2	2
8. Mudstone, light olive gray (5Y5/2), silty, iron-stained, weathers into a convex upward mudcracked slope, spongy and cohesive when wet (bentonitic), non-calcareous, occasional manganiferous concretion.	21	8
7. Sandstone, as in unit 5.	2	8
6. Siltstone, brownish-black, very sandy, abundant black carbonaceous material, non-calcareous.	1	4
5. Sandstone, as in unit 4, friable, interbedded shale, dark yellowish-brown, carbonaceous material, sandy.	14	2
4. Sandstone, dusky yellow (5Y6/4), weathers yellowish-gray (5Y7/2), dark yellowish-orange (10YR6/6) iron stains, fine to very fine-grained, non-calcareous, friable.	4	10
3. Siltstone, brownish-black (5YR2/1), sandy, clayey, compact, much carbonaceous material, non-calcareous.	2	6
2. Shale and mudstone, dark yellow-brown (10YR4/2), compact to flaky, mudcracked and convex upward slope (bentonitic), non-calcareous, fine-grained sand lenses, partly carbonaceous.	19	4
1. Sandstone, light gray (N7), friable except lo-		

cally cemented by calcite, strongly cross-bedded, lenticular carbonaceous and macerated plant accumulations, very dusky red purple (5RP2/2) manganiferous concretions, medium to fine-grained, silty and clayey.	11	0
Total	100	4

SECTION 10-62 NW 1/4 NE 1/4 sec. 31, T. 141 N., R. 80 W.
Missouri River Section
Roadcut between two buttes, north of curve in road.

Tertiary – Tongue River Formation	**Feet**	**Inches**
7. Conglomerate, as in unit 5, forms resistant cap on butte, lenticular, cross-bedded; sandstone, very pale orange (10YR8/2), strongly cross-bedded, fine to very fine-grained calcareous, very thinly bedded.	17	6
6. Sandstone, yellowish-gray, very calcareous, very fine-grained, cliff former, variable bedding (less than an inch to 2 ft.), cross-bedded.	19	4
5. Conglomerate, rounded limestone particles, sandstone matrix, pale yellowish-brown (10-YR6/2), weathers light brown and grayish-orange, variable bedding (over 4 ft. to 3 in.); sandstone, yellowish-gray, very fine-grained, cross-bedded, cliff former.	6	0
4. Sandstone, yellowish-gray (5Y8/1), very fine-grained, silty, friable and indurated, calcareous cement, thinly bedded, cliff base.	3	1
3. Covered interval, slope wash.	84	2
2. Sandstone and sand, grayish-olive (10Y4/2) and light olive gray (5Y5/2), medium to fine-grained, cross-bedded, mostly friable, petrified wood fragments, easily eroded by wind (blowout), non-calcareous, abundant dark mineral grains, "basal sandstone" unit of the Tongue River Formation.	24	2
Tertiary – Cannonball Formation		
1. Shale and siltstone, moderate yellowish-brown (10YR5/4) and light olive gray (5Y5/2), calcareous, interbedded, soft, flaky to fissile, scattered carbonaceous fragments, thinly bedded.	6	0
Total	160	3

SECTION 11-62 NW corner NW 1/4 SW 1/4 sec. 10, T. 140 N., R. 79 W.
Test Hole 2038 Section
East roadcut, outcrop above test hole.

Tertiary — Tongue River Formation	Feet	Inches
4. Limestone, as in unit 2.	3	0
3. Shale, dark yellowish-orange (10YR6/6), very silty, calcareous, flaky to fissile, soft, interbedded sandstone, friable, dusky yellow, medium to fine-grained.	2	0
2. Limestone, yellowish-gray (5Y7/2) and light olive gray (5Y5/2), sublithographic, fractured into a rubble, argillaceous, lenticular, ferruginous staining.	2	11
1. Sandstone, dusky yellow (5Y6/4), indurated to friable, calcareous cement, strongly crossbedded, thinly bedded (1-2 in.), medium to fine-grained, "salt and pepper" appearance due to abundant dark mineral grains, ferruginous concretions.	7	2
Total	15	1

SECTION 12-62 NE corner sec. 20, T. 138 N., R. 75 W.
Test Hole 2025 Section
West roadcut, exposure above test hole.

Pleistocene — Ice-contact lacustrine	Feet	Inches
2. Covered interval, top of hill.	5	0
1. Silt and clay, interbedded dusky yellow (5Y-6/4) and light olive gray (5Y5/2), laminae bedding (1 mm), calcareous, blocky to flaky.	12	3
Total	17	3

SECTION 13-62 NE 1/4 NE 1/4 SE 1/4 sec. 27, T. 140 N., R. 81 W.
Missouri River Trench Shell Section
South side of gully on east side of river road. 0.25 mile NW of road junction.

Recent Alluvium	Feet	Inches
10. Soil and windblown material, olive gray.	2	0
Pleistocene — Outwash and lacustrine		
9. Sand, grayish-orange (10YR7/4) and light gray, very poorly sorted, clayey and silty, very coarse to very fine-grained, mostly medium to fine-grained, calcareous.	2	3

8. Marl, very light gray (N8) and silt, light gray (N7), very fossiliferous (molluskan), extremely calcareous, lenticular, interbedded dark yellow orange sand, medium to fine-grained.	1	5
7. Sand, yellowish-gray and dark yellowish-orange (10YR 6/6), well sorted, fine to very fine-grained, non-calcareous.	4	10
6. Gravel, medium size, about 50 percent sand, poorly sorted, mostly igneous, limestone, and local bedrock particles.	3	4
5. Clay, dusky yellow, very silty, poorly bedded, very calcareous.	3	8
4. Clay, olive gray (5Y 3/2) and light olive gray (5Y 5/2), interbedded yellowish-gray (5Y 7/2) silt, calcareous.	3	4
3. Gravel, fine to medium size, mostly reworked local bedrock particles, detrital snails from Tongue River Formation.	1	10
2. Sand, dusky yellow (5Y 6/4), medium to very fine-grained, mostly fine to very fine-grained, poorly sorted, silty, calcareous.	2	9
Tertiary — Cannonball Formation		
1. Shale, grayish-orange and light olive gray (5Y 6/1), blocky, light brown (5YR 5/6), ferruginous stains along the bedding and fracture planes, very silty, non-calcareous.	7	2
Total	32	7

SECTION 14-62 NE 1/4 NE1/4 SE 1/4 sec. 11, T. 104 N., R. 80 W.
School No. 3 Section
West roadcut, north side of hill.

Tertiary — Tongue River Formation ("basal sandstone")	**Feet**	**Inches**
3. Sandstone and sand, dusky yellow (5Y 6/4), medium to fine-grained, poorly sorted, locally calcareous cemented, abundant dark mineral grains, friable, easily eroded by wind (blowout), petrified wood fragments; contact with Cannonball Formation is marked by claystone ferruginous concretions and fragments, moderate yellowish-brown and grayish-red; disconformable contact.	15	6
Tertiary — Cannonball Formation		
2. Shale, olive black (5Y 2/1), fissile, carbonace-		

ous, non-calcareous; sands, siltstones, and claystone, dusky yellow (5Y 6/4) and light olive gray, friable, slightly calcareous to non-calcareous.	16	1
1. Shale, siltstone, and sandstone, interbedded, moderate yellowish-brown (10YR 5/4) and light olive gray (5Y 5/2), very thinly bedded, calcareous, fine to very fine-grained friable sand, few sandstone concretions.	15	0
Total	46	7

SECTION 15-62 SE 1/4 SW 1/4 sec. 31. T. 139 N., R. 79 W.
Trailer Park Section
North roadcut, 0.3 mi. west of sec. corner.

	Feet	Inches
Tertiary – Cannonball Formation		
5. Covered interval	4	10
4. Sandstone, siltstones, and shale, interbedded, soft, friable, yellowish-gray, light olive gray, and dusky yellow, calcareous, fine to very fine-grained sand, thinly bedded, ironstone concretions.	14	6
Tertiary – Ludlow Formation		
3. Shale, brownish-gray (5YR 4/1) and brownish-black (5YR 2/1), carbonaceous, lignitic, silty non-calcareous.	2	0
2. Siltstone, light olive gray (5Y 6/1), friable, very fine, sandy, shaly, abundant carbonaceous fragments, thinly bedded, non-calcareous, iron stained.	7	6
1. Sandstone, dusky yellow (5Y 6/4), friable, fine to very fine-grained, ferruginous staining, ironstone concretions, thinly bedded, non-calcareous.	4	8
Total	33	6

APPENDIX B

SUMMARY OF EXPLORATORY WELLS

N.D.G.S. Well Number	19	145	151	155	174	701	723
N.D.G.S. Permit Number		161	167	171	190	714	736
N.D.G.S. Circular Number		21	33	39	42		
Operator	Continental-Pure	Continental-Pure	Hunt	Continental	Continental	Caroline Hunt	Caroline Hunt
Well Name	Davidson #1	P. H. McCay #1	Emma Kleven #1	N. Dronen #1	Duemeland #1	Board Univ. & School Lands #1	R. P. Schlabach #1
Location	6-140N-77W	32-137N-76W	18-140N-80W	9-140N-75W	3-140N-77W	36-144N-75W	36-139N-76W
Date Drilled	1949	1952	1952	1952	1952	1954	1954
Elevation Kelly Bushing	1909	1869	1922	1912	1981	2023	1877
Total Depth	6957	6185	8115	6155	6864	6300	5859
Surface Rocks	Cannonball	Pleistocene	Cannonball	Pleistocene	Cannonball	Pleistocene	Pleistocene
Mechanical Log—Depth to Formation Tops							
Cretaceous-Fox Hills	353					397	
K. – Pierre	630	377	890	473	710	703	424
K. – Niobrara	1629	1323	1910	1428	1687	1671	1391
K. – Greenhorn	2170	1896	2482	1971	2218	2118	1920
K. – Mowry	2533	2263	2840	2343	2538	2460	2290
K. – Fall River	2812	2522	3126	2593	2857	2697	2544
Jurassic-Swift	2924	2798	3360	2704	2984	2943	2725
J. – Rierdon	3249	2963	3697	2989	3310	3147	2997
Pennsylvanian-Minnelusa			3938				
P. – Amsden	3542	3199	4056	3274	3587		3287
P. – Tyler	3699	3360	4357	3293	3697	3455	3293
Mississipian-Kibbey			4502				
M. – Madison-Poplar	3867		4539	3430	3850	3568	
M. – Madison-Ratcliffe	3961	3507	4690	3458	3930	3648	3473
M. – Madison-Frobisher Alida	4078	3630	4837	3599	4048	3741	3582
M. – Madison-Tilston	4296	3818	5043	3770	4266	3932	3753
M. – Madison-Bottineau	4438	3923	5183	3892	4400	4056	3880
M. – Bakken	5002		5810		4952	4580	
Devonian-Three Forks			5830				
D. – Birdbear	5009	4407	5850	4418	4960	4597	4361
D. – Duperow	5072	4470	5915	4455	5018	4634	4425
D. – Souris River	5254	4614	6129	4632	5197	4832	
D. – Dawson Bay	5357		6260	4697	5292	4935	
D. – Prairie	5432		6350	4752	5350	5000	
D. – Winnipegosis			6370				
Silurian-Interlake	5485	4720	6432	4782	5380	5053	4740
Siluro-Ordovician-Stonewall	5628	4803	6671		5553	5184	4803
Ordovician-Stony Mountain	5690	4850	6730	4920	5620	5243	4870
O. – Stony Mountain Shale	5750	4922	6799	4995	5679	5303	4923
O. – Red River	5850	5020	6897	5090	5774	5401	5024
O. – Winnipeg-Roughlock	6498	5608	7557	5686	6398	6022	5623
O. – Winnipeg-Icebox	6537	5683	7600	5744	6449	6071	5687
O. – Winnipeg-Black Island	6664	5811	7728	5873	6577	6198	5818
Cambro-Ordovician-Deadwood	6684	5828	7773	5887	6594	6220	5833
Precambrian	6946	6163	8088	6144	6861		

SUMMARY OF EXPLORATORY WELLS

N.D.G.S. Well Number	756	763	765	772	1371	1375	1409
N.D.G.S. Permit Number	769	776	778	785	1383	1387	1421
N.D.G.S. Circular Number				177	188		222
Operator	Caroline Hunt	Caroline Hunt	Caroline Hunt	Caroline Hunt	Continental-Pure	Continental	Leach-Calvert
Well Name	R. A. Nicholson #1	Anton Novy #1	Soder Investment #1	Paul Ryberg #1	J. F. Miller #1	Patterson Land Co. #1	Patterson Land Co. #1
Location	32-137N-77W	14-144N-77W	31-142N-76W	23-140N-79W	30-143N-75W	15-141N-75W	11-140N-77W
Date Drilled	1954	1954	1954	1954-1955	1957	1957	1957
Elevation Kelly Bushing	1891	1947	2027	2007	2051	2073	2019
Total Depth	6157	6919	6750	7230	4290	4160	6595
Surface Rocks	Hell Creek	Pleistocene	Cannonball	Cannonball	Pleistocene	Pleistocene	Pleistocene
Mechanical Log - Depth to Formation Tops							
Cretaceous-Fox Hills		410	460	520	392	364	
K. – Pierre	442	710	784	822	710	654	706
K. – Niobrara	1422	1710	1750	1811	1680	1622	1678
K. – Greenhorn	2000	2235	2268	2370	2184	2153	2212
K. – Mowry	2376	2597	2637	2740	2535	2517	2588
K. – Fall River	2645	2854	2899	3011	2783	2773	2853
Jurassic-Swift	2820	3097	3031	3243	3082	2895	2963
J. – Rierdon	3103	3399	3367	3539	3274	3183	3302
Pennsylvanian-Minnelusa							
P. – Amsden	3313	3670	3668	3840		3486	3591
P. – Tyler	3478	3727	3740	4093	3594	3509	3687
Mississipian-Kibbey							
M. – Madison-Poplar	3618	3880	3890	4270	3724	3650	3829
M. – Madison-Ratcliffe	3697	4010	3993	4333	3811	3684	3855
M. – Madison-Frobisher Alida	3830	4129	4118	4490	3952	3821	4018
M. – Madison-Tilston	4008	4344	4323	4695	4136	3989	4218
M. – Madison-Bottineau	4152	4486	4452	4830	4273	4122	4355
M. – Bakken	4670	5073	5042	5432			4912
Devonian-Three Forks							
D. – Birdbear	4677	5096	5050	5457			4918
D. – Duperow	4715	5146	5093	5514			4975
D. – Souris River	4880	5352	5283	5704			5153
D. – Dawson Bay	4959	5490	5392	5808			5256
D. – Prairie	5007	5573	5448	5881			5310
D. – Winnipegosis		5600					
Silurian-Interlake	5039	5640	5490	5929			5368
Siluro-Ordovician-Stonewall	5089	5834	5654	6132			5483
Ordovician-Stony Mountain	5160	5895	5720	6197			5550
O. – Stony Mountain Shale	5217	5959	5780	6264			5610
O. – Red River	5312	6053	5880	6361			5709
O. – Winnipeg-Roughlock	5904	6704	6514	7008			6326
O. – Winnipeg-Icebox	5974	6745	6562	7057			6380
O. – Winnipeg-Black Island	6103	6873	6686	7177			6507
Cambro-Ordovician-Deadwood	6120	6898	6717	7230			6523
Precambrian							

THE FOSSIL MOLLUSCAN FAUNA OF PLEISTOCENE SEDIMENTS OF BURLEIGH COUNTY, NORTH DAKOTA

by

Samuel J. Tuthill

INTRODUCTION

Thirty specific and subspecific taxa of nineteen genera are represented in the Pleistocene fossil molluscan fauna of Burleigh County. These collections are stored at the Department of Geology, University of North Dakota, Grand Forks, North Dakota. Gastropods of the families Viviparidae, Valvatidae, Hydrobiidae, Lymnaeacea, Planorbidae, Physidae, Pupillidae, Valloniidae, Succineidae, Endodontidae, and Zonitidae and pelecypods of the families Unionidae and Sphaeridae occur. These fossils were found at twenty-three sites (see fig. 26, table 5) by Kume and Hansen. They collected bulk samples which I examined. They are responsible for the lithologic and stratigraphic information, and I am responsible for the identifications of fossils and paleoecology.

About 500 ml of sediments from each bulk sample were wet sieved in a series of micropaleontological sieves (Tyler series 20, 40, 60, 80, and 100 mesh) and the fossils were removed under binocular microscope magnification of 15X and 45X. References used in identification of the fossil mollusks were: Dall (1905), Baker (1928a, 1928b, and 1945), van der Schalie (1933), Pilsbry (1946, 1948), Hubendick (1951), Leonard (1950, 1952), Taylor (1960) and Herrington (1962).

The species represented in the Pleistocene fauna of Burleigh County are, with the exception of **Viviparus**, all still extant in North Dakota. **Viviparus** sp., found at the Apple Creek site is not of Pleistocene age, in my opinion, but rather a reworked fossil from the Paleocene Tongue River Formation. This may also be true of some of the **Sphaerium** sp. specimens.

The ecology of the various species in their modern environments, insofar as it is known, was used for paleoecologic reconstructions.

Since none of the species are extinct, they cannot provide indices for geologic age of the sediments; however, their shell material may supply chronologic data through radiocarbon analyses and several sites in Burleigh County have been dated. Faunules in the Missouri Coteau district, which are dominated by the branchiate genera **Valvata** and **Amnicola,** are very different from the Recent aquatic molluscan fauna and are therefore regarded as pre-Recent. This idea is borne out by studies elsewhere in the Missouri Coteau district where radiocarbon data are available.

Sound paleoecologic reconstructions require evaluation of several aspects of the relationship of the sediments and the fauna. The matter of whether the fossils have been transported from older sediments or from contemporaneous environments in other geographical locations must be considered. The ecologic requirements of the various species can be inferred from the ecologic requirements of related Recent forms. If the stratigraphic and lithologic relationships of the sediments which contain the fossils is in essential agreement with the ecologic requirements of the fossil species, it is assumed that the fossils represent the biota which was living at the time, and roughly in the place, in which deposition occurred. This assumption is safer when lake faunas are found in lake sediments, and less safe when stream faunas are found in stream sediments. This is because the criteria by which the stream origin of sediments are recognized implies transport and sorting of fossil shells as well as the containing sediments. When specimens of a species comprise a significant element of the total fauna and require ecologic conditions other than those indicated by the lithology, the fossil assemblage is assumed to be a thanatacoenose.

1. Billingmeier Ranch site
2. Salt Lake site
3. Florence Lake site
4. Muller Ranch site 1
5. Muller Ranch site 2
6. Detlef Ranch site
7. Wheelock Ranch site
8. Painted Woods site
9. Pelican Lake site
10. Boynton Ranch site
11. Harris Ranch site 1
12. Harris Ranch site 2
13. Blekkinsh Ranch site
14. McDonald Ranch site
15. Coonan Ranch site
16. Stopp Ranch site
17. Hay Creek site
18. Griffin Ranch site
19. Harvey Ranch site
20. Apple Creek site 1
21. Johnson Ranch site
22. Haberlin Ranch site
23. Blackman Ranch site

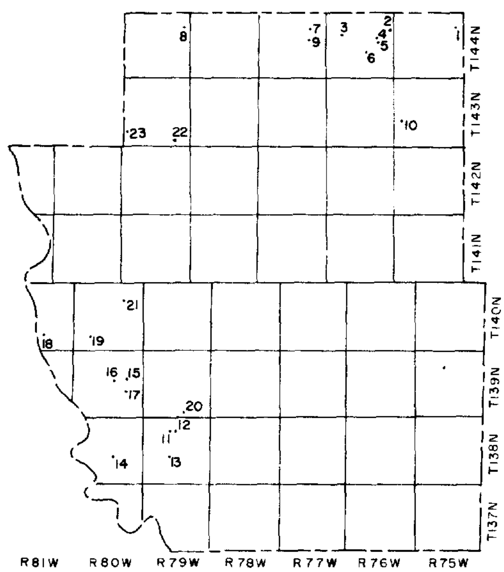


Figure 26. Locations of the fossil molluscan fauna sites in Burleigh County.

Because of the complex nature of any drainage system, finite microhabit types are not found in disjunct units or discrete geographic relationships throughout the system. Any drainage is a complex of gradational molluscan habitats (Tuthill, 1963, p. 24-29), many of which have similar characteristics, both as to type of sediment and fauna. While suggesting great caution in paleoecologic reconstructions, this complexity of the modern drainage system does not depreciate the usefulness of fossil mollusks as clues to the environments which existed during the past. Where species requiring diverse ecologic conditions are mixed, the paleoecologist can reason that the various habitats indicated did, indeed, exist in the drainage system, but the point of deposition represents a composite picture of ecologic conditions within that drainage system.

The radiocarbon dates on fossil mollusk shells do not date the underlying sediments (i.e. tills) except to indicate a minimum age. This limitation is of importance in Burleigh County as the sediments of the Missouri Coteau district are assumed to be younger than those in the Coteau Slope district on the basis of geomorphological evidence. The molluscan faunas of the two districts are dissimilar in certain aspects, (table 5) suggesting a possible dissimilarity in age. An alternate explanation is that the nature of the differences between the molluscan faunas of the two districts may represent different ecologic conditions. Such conditions may have existed at the same or at different times.

MOLLUSCAN FAUNA

The following thirty taxa of mollusks were taken from the twenty-three samples from Burleigh County, North Dakota:

Phylum MOLLUSCA
- Class PELECYPODA
  - Order EULAMELLIBRANCHIA
    - Superfamily NAIADAE
      - Family UNIONIDAE
        - Naiad Fragments
  - Order TELEODESMACEA
      - Family SPHAERIDAE
        - **Sphaerium** spp.
        - **Pisidium** spp.
- Class GASTROPODA
  - Subclass STREPTONEURA
    - Order MESOGASTROPODA
      - Superfamily VIVIPARACEA
        - Family VIVIPARIDAE
          - **Viviparus** sp.
      - Superfamily VALVATACEA

Family VALVATIDAE
Valvata lewisi Currier, 1868
Valvata tricarinata (Say), 1817
Superfamily RISSOACEA
Family HYDROBIIDAE
Amnicola limosa (Say), 1817
Subclass EUTHYNEURA
Order BASSOMATOPHORA
Superfamily LYMNAEACEA
Family LYMNAEIDAE
Lymnaea palustris (Müller), 1774
Lymnaea humilis (Say), 1822, (sensu Hubendick)
Lymnaea stagnalis (Linne), 1758
Lymnaea sp.
Superfamily ANCYLACEA
Family PLANORBIDAE
Gyraulus parvus (Say), 1817
Gyraulus sp.
Promenetus exacuous (Say), 1821
Armiger crista (Linne), 1758
Helisoma trivolvis (Say), 1817
Helisoma campanulatum (Say), 1821
Helisoma anceps (Menke), 1830
Helisoma sp.
Family PHYSIDAE
Physa cf. P. gyrina (Say), 1821
Physa sp.
Order STYLOMATOPHORA
Suborder ORTHURETHRA
Superfamily PUPILLACEA
Family PUPILLIDAE
Gastrocopta armifera (Say), 1821
Pupilla blandi Morse, 1865
Family VALLONIIDAE
Valonia gracilicosta Reinhardt, 1883
Valonia sp.
Suborder HETERURETHRA
Superfamily SUCCINEACEA
Family SUCCINEIDAE
Catinella grosvenori (Lea), 1864
Catinella grosvenori gelida (Baker), 1927
Succinea avara (Say), 1824
Suborder SIGMURETHRA
Infraorder AULACOPODA
Superfamily ENDODONTACEA
Family ENDODONTIDAE
Discus cronkhitei (Newcomb), 1865

Superfamily ZONITACEA
Family ZONITIDAE
Zonitoidea arborea (Say), 1816

I believe that one taxon, **Viviparus** sp., is not of Pleistocene Age. Ostracod carapaces and stems and oögonia of calcareous algae, probably of the genus **Chara**, were also found in the sediments.

The twenty-three locations were given informal site names, taken from the ranch name, or the township name in which they occur. The Plat book in the library of the North Dakota Geological Survey was the source of these names. Geographic distribution of these sites is shown in fig. 26. The location, nature of the sediments, probable aquatic environment as reconstructed from the faunal assemblage, grain size of the sediments, fauna, and pertinent remarks are given below for each site. The fauna of the Coteau Slope district (table 5) has striking differences from those taken from the sediments of the Missouri Coteau district. The lack of naiads and the greater number and variety of terrestrial snails in the Coteau Slope district suggests drier conditions for the environment than that postulated (Tuthill, 1963) for the Missouri Coteau in eastern Burleigh, McIntosh, Stutsman, Logan, Sheridan, and Divide Counties. The presence of **Valvata tricarinata, Amnicola limosa,** and **Viviparus** sp. makes this fauna different from the present molluscan fauna of the region, insofar as the latter is known. The disjunct nature of the geographic distribution of the terrestrial and aquatic elements of the Pleistocene molluscan fauna is shown on figs. 27 and 28. The number of aquatic taxa (specific and subspecific rank) in each faunule as a percent of the total number of aquatic taxa found in Burleigh County has been made into an isopleth map (fig. 27). The occurrence of **Viviparus** sp. has been ignored in this treatment. **Helisoma** sp. has not been regarded as a separate taxon because of the slight likelihood that it represents another species than those given in the systematic list. Thus the denominator for the percentage relationship is 19 rather than the 21 found in the systematic list and on table 5.

Essentially the same procedure was followed for the terrestrial snails. Eight taxa of snails formed the denominator of this relationship and the results may be seen on fig. 28.

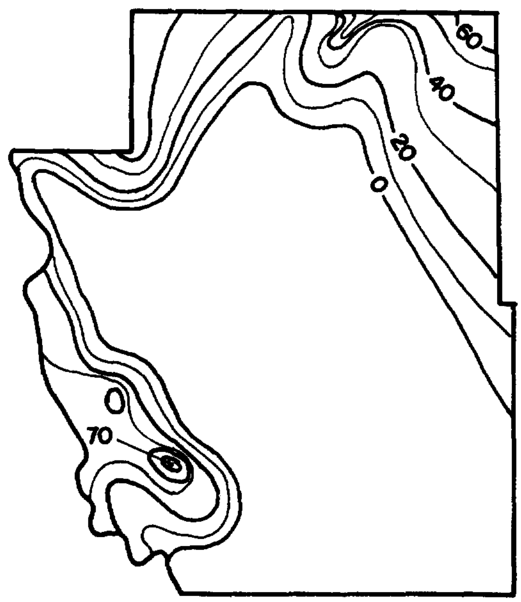
The relative number of branchiate (gill-breathing) gastropod species and pelecypod species in each site faunule as a function of the total number of species present, has been converted to a percentage and an isopleth map, showing the geographic distribution of these relationships, has been made (fig. 29).

This treatment of the data points up the existence of two areas in Burleigh County, which, during pre-Recent Pleistocene time, contained permanent bodies of water which did not concentrate salts by excessive evaporation, as in the case in the entire county at present. This indicates that the evapo-transpiration vs. precipitation ratio of the area must have been a positive value rather than a negative one.

The specimens of **Viviparus** sp. are probably reworked Tongue River Formation fossils. **Valvata** and **Amnicola** have not been described from the Tongue River Formation and the condition of the shell material and the stratigraphy of the collection sites indicates that they are probably of Pleistocene age. However, they may represent additions to the resident fauna transported by meltwater from the Missouri Coteau district during late Wisconsin time.

FOSSILIFEROUS SITES IN THE MISSOURI COTEAU DISTRICT

The following sites in Burleigh County were discovered and collected by D. E. Hansen.



Isopleth Interval — 10 Per Cent

Fig. 27. Percent of the Total Pleistocene Aquatic Mollusk Species Represented in Individual Site Faunules as a Function of Geographic Distribution ($\frac{Sa}{Ta} \times 100 = \%$, where Ta = Total Number of Pleistocene Aquatic Species found in Burleigh County (12) and Sa = Number of Pleistocene Aquatic Species found in Individual Site faunules.)

1. Billingmeier Ranch site: – This site is in the NW 1/4 sec. 12, T. 144 N., R. 75 W. The few fossils recovered were contained in silty marl taken from dead-ice moraine of the Burnstad Drift.

Faunal list:	Gastropods:	**Gyraulus parvus**
		Gyraulus sp.
	Pelecypods:	**Sphaerium** sp.

Probable Environment: – The marl and silt suggest a well oxygenerated pond. The molluscan fossils indicate that seasonally temperate water was present at some time.

2. Salt Lake site: This site is in the NE 1/4 SE 1/4 sec. 12, T. 144 N., R. 76 W. The samples were collected from light tan to light grayish-brown silt and clay from stagnation features of the Burnstad Drift.

Faunal list:	Pelecypods:	**Pisidium** sp.
	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Helisoma anceps
		Gyraulus parvus

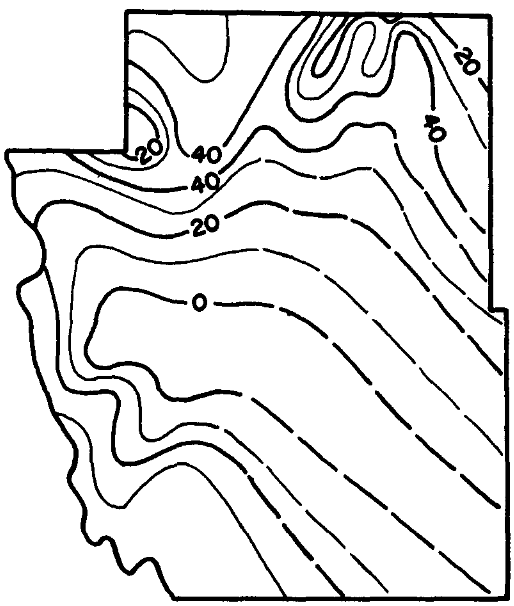


Fig. 28. Percent of the Total Pleistocene Terrestrial Mollusk Species Represented in Individual Site Faunules as a Function of Geographic Distribution. ($\frac{St}{Tt}$ x 100 = %, where St = the Total Number of Pleistocene Terrestrial Species found in Burleigh County (8) and Tt = the Number of Pleistocene Terrestrial Mollusk Species found in Individual Site Faunules.)

Probable Environment: – Shallow lake.

3. Florence Lake site: – This site is in the NW1/4 NW1/4 sec. 17, T. 144 N., R. 76 W. The samples were collected from very light tan silty marl, which is interbedded with gravel, in an area of collapsed outwash on the distal side of the Streeter Moraine of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Lymnaea humilis
		Helisoma campanulatum
		H. anceps
		Gyraulus parvus
		Promenetus exacuous

Probable Environment: – Stream.

4. Muller Ranch site 1: – This site is in the NE1/4 NE1/4 sec. 14, T. 144 N., R. 76 W., 0.25 miles west of the NE section corner. The fossils were enclosed in silts of the Burnstad Drift.

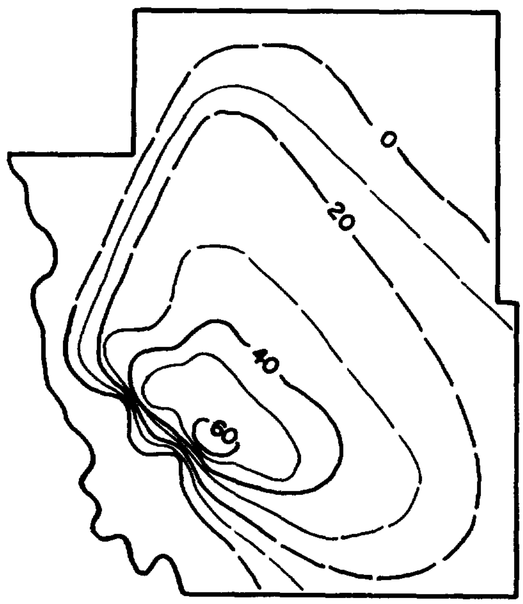


Fig. 29. Branchiate Gastropod and Pelecypod Species in each Site Faunule as a percent of the Number of Species in each Site Faunule as a Function of Geographic Distribution. $\frac{Gb + P}{St + Sa} \times 100 = \%$, where Gb = Branchiate Gastropod Species, P = Pelecypod Species, and St and Sa are as described in Fig. 2 and 3.)

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Lymnaea sp.
		Gyraulus parvus
		Gyraulus sp.
		Promenetus exacuous
	Pelecypods:	**Pisidium** sp.

Probable Environment: – Shallow lake.

5. Muller Ranch site 2: – This site is 0.25 miles south of the section corner of NW1/4 NW1/4 sec. 14, T. 144 N., R. 76 W. The samples were collected from a thin bed of silty marl, near the base of the exposure, in collapsed outwash sediments of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Lymnaea sp.
		Helisoma anceps
		Gyraulus parvus
		Gyraulus sp.
		Armiger crista
	Pelecypods:	**Pisidium** sp.
		Naiad fragments

Probable Environment: – Stream or shallow lake. Although the aquatic pulmonates are very numerous, **V. tricarinata** is an important part of the fauna. Permanent water was undoubtedly present throughout the time that the fauna lived. Vegetation, both marginal and aquatic, was probably present and the water was temperate during the warm season.

6. Detlef Ranch site: – This site is in the NE1/4 NW1/4 sec. 22, T. 144 N., R. 76 W., 0.6 miles west of Highway 14. Samples were collected from silty marl in collapsed outwash deposits on the distal side of the Streeter Moraine of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Helisoma campanulatum
		Lymnaea sp.
		Gyraulus sp.
		Promenetus exacuous

Probable Environment: – Shallow lake.

7. Wheelock Ranch site: – This site is 0.6 miles south of the NW section corner in the NW1/4 SW1/4 sec. 11, T. 144 N., R. 77 W. Samples were collected from a silty marl bed, which is about three

feet thick, in dead-ice moraine deposits of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Lymnaea cf. L. humilis
		Helisoma campanulatum
		H. anceps
		Gyraulus parvus
		Gyraulus sp.
		Promenetus cf. P. exacuous
	Pelecypods:	**Pisidium** sp.

Probable Environment: – Shallow lake.

8. Painted Woods site: – This site is 0.7 miles east of the NW corner sec. 12, T. 144 N., R. 79 W. The samples were collected from a very light tan silty marl bed, overlying clay and sand, and interfingering with till, in dead-ice moraine deposits of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Helisoma campanulatum
		Physa cf. P. gyrina
		H. anceps
		Gyraulus parvus
		Gyraulus sp.
		Promenetus excauous
		Armiger crista
	Pelecypods:	**Sphaerium** spp.
		Pisidium spp.

Probable Environment: – Shallow lake.

9. Pelican Lake site: – This site is in the NW1/4 SW1/4 sec. 13, T. 144 N., R. 77 W. The samples were collected from marl deposits on the edge of a kettle in dead-ice moraine.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Gyraulus sp.
	Pelecypods:	**Pisidium** spp.

Probable Environment: – Shallow lake. Marl suggests standing, clear permanent water bodies. The fauna, although it is small and simple, supports this idea.

10. Boynton Ranch site: – This site is 0.5 miles south of NE corner sec. 19, T. 143 N., R. 75 W. Samples were collected from a four foot bed of light brownish-gray sandy and silty clay of

dead-ice moraine deposits of the Burnstad Drift.

Faunal list:	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Helisoma anceps
		Gyraulus parvus
		Gyraulus sp.
		Promenetus excauous
		Armiger crista
	Pelecypods:	**Pisidium** spp.

Probable Environment: – Shallow lake.

FOSSILIFEROUS SITES IN THE COTEAU SLOPE DISTRICT

The following sites in Burleigh County were discovered and collected by Mr. Jack Kume.

11. Harris Ranch site 1: –– This site is in a road cut in the NW1/4 NE1/4 sec. 9, T. 138 N., R. 79 W. just south of the bridge on old U.S. Highway 10, approximately four miles east of Bismarck. The sediments are fine to medium-grained sand. The fauna was transported, but the shells are only slightly worn and could not have been carried far.

Faunal list:	Pelecypods:	**Sphaerium** sp.
	Gastropods:	**Valvata tricarinata**
		Amnicola limosa
		Helisoma trivolvis

Probable Environment: – The number of specimens taken from this site is small. The sediments indicate a stream environment of deposition. **Valvata** and **Amnicola** are presently found in the eastern part of North Dakota and in the Coteau Slope district in Logan and Kidder Counties. The **Amnicola limosa** living in eastern North Dakota at present are found exclusively in streams, most of which are capable of transporting coarse sand or finer sediments during part of the year. **Valvata** have been found only in lakes in North Dakota, but are known in streams elsewhere in the Midcontinent. **Sphaerium** is not out of place in streams. **Helisoma trivolvis** is typically found in standing bodies of water, characterized by finer grained sediments. Its inclusion in sediments of sand size may be explained by the fact that the margins of most streams have microhabitats suitable to the species and these specimens may have lived in backwaters and then been floated or carried into the faster currents after death. **Valvata** and **Amnicola** are both branchiate forms and also require relatively clear water.

The fauna represents a drainage system which was clear, except possibly in periods of flood, seasonally temperate, and vegetated with both aquatic and marginal plants.

12. Harris Ranch site 2: — This site is located in NW1/4 NE1/4 sec. 9, T. 138 N., R. 79 W., in the south road ditch at the same location as Harris Ranch site 1. The sample was taken from 16 to 22 feet below the surface in test hole 1861. The sediments are coarse silt and fine to medium-grained sand indicating a fluviatile environment of deposition. The fauna was probably carried a short distance from its place of life.

Faunal list:	Pelecypods:	**Sphaerium** sp.
		Pisidium sp.
	Gastropods:	**Amnicola limosa**
		Gyraulus parvus
		Helisoma anceps
		Physa sp.

Probable Environment: — The sediments were probably deposited in relatively quiet water in a stream. The pulmonate species **Gyraulus parvus** and **Physa** sp. are typical of the subhumid areas of North Dakota today. **Helisoma anceps** is considered by Baker (1928, p. 319) to be a river and stream form. This species has been collected in North Dakota only from the Cannonball River in Grant County, but it is common in late Wisconsin sediments of the Missouri Coteau district. **Amnicola limosa** is currently a stream form, and **Sphaerium** and **Pisidium** are both found in stream environments in North Dakota today. Thus, while the fauna was no doubt transported to some minor degree, it is a reasonable assemblage for stream laid sediments. These two species of pelecypods (**Sphaerium** and **Pisidium**) strongly dominate the fauna, representing 46 percent of the individuals. **Amnicola limosa** is the least frequent of the species (three percent). If the frequency distribution of species has any validity for determining environment, it would seem that conditions during the lives of the fossil mollusks were not much different from those now existing in the Coteau Slope district.

13. Blekkinsh Ranch site: — This site is in a roadcut on the south side of a section-line road on the side of a coulee in NW1/4 NE1/4 sec. 21, T. 138 N., R. 79 W. The sediments are silt-sized.

Faunal list:	Pelecypods:	**Pisidium** sp.
	Gastropods:	**Lymnaea palustris**
		Gyraulus parvus
		Helisoma trivolvis
		Promenetus excauous
		Armiger crista
	Other Fossils:	**Ostracods**
		Chara sp.

Probable Environment: — Shallow lake. This faunal assemblage is identical with that of the present Coteau Slope district as reported by Tuthill and Laird (1963). It is an assemblage which could exist in a recent permanent or ephemeral slough. **Lymnaea**

palustris and **Gyraulus parvus** comprise 30.9 percent and 29 percent of the fauna, respectively. There are no branchiates among the gastropods and **Pisidium** is known to inhabit nearly amphibious habitats. Thus the sedimentary and faunal evidence suggest a slough type environment which may or may not have been a permanent body of water.

14. McDonald Ranch site: – This site is in the NW corner SW1/4 sec. 22, T. 138 N., R. 80 W. The fossils were found directly beneath the soil zone in a bluff which is five and one half feet thick, composed of silty to sandy soil and clay.

Faunal list:	Pelecypods:	**Sphaerium** sp.
	Gastropods:	**Lymnaea humilis**
		Lymnaea stagnalis
		Gyraulus parvus
		Physa sp.
	Other Fossils:	**Ostracods**

Probable Environment: – Shallow lake. Like the fauna at the Blekkinsh Ranch site, this assemblage and the sediments which contain it suggest deposition in a slough which may or may not have been a permanent body of water. All species are common in the Coteau Slope district today. The stratigraphy of the site suggests that the sediments are of late Wisconsin Age, but the possibility that they are of Recent Age is not precluded by the fossil assemblage.

15. Coonan Ranch site: – This site is in a fresh roadcut on the west side of the section-line road in the SE1/4 NE1/4 sec. 14, T. 139 N., R. 80 W. Samples were collected from a local lense of outwash sand associated with till and clay at the crest of a bedrock knoll.

Faunal list:	Gastropods:	**Viviparus** sp.
		Vallonia gracilicosta
		Catinella grosvenori
		Pupilla blandi
		Discus cronchitei

Probable Environment: – Stream bank or floodplain. All of the gastropods in this fauna are terrestrial forms except **Viviparus**, which I believe is reworked from Tongue River Formation sediments and is not a part of the Pleistocene fauna of Burleigh County. This idea stems from the worn condition of the Viviparidae specimens I have examined, and the fact that the Tongue River Formation is the immediate sub-Pleistocene bedrock of this part of the county.

The fauna from this site may be of pre-Recent age, and if it is, it is of considerable significance in that the large number of terrestrial species in the Coteau Slope district of western Burleigh County is in striking contrast with the paucity of land snails in the Missouri Coteau district. This might be accounted for by the fact that the Coteau Slope district faunas represent a terrestrial-fresh-water bio-facies, while the Coteau district faunas represent a superglacial aquatic bio-facies. Thus, the Coteau Slope district faunas are typified by pulmonates, both Bassomatophora and Stylomatophora, while the Coteau district faunas are typified by a general dominance of branchiate snails. The fact that both areas are typified by a pulmonate Recent aquatic snail fauna and the Recent terrestrial snail fauna has not been studied, is a complicating factor. Thus one must rely on stratigraphic criteria or radiocarbon dating for establishment of geologic age.

16. Stopp Ranch site: – The site is on the south side of the section-line road in SE1/4 SE1/4 sec. 15, T. 139., N. R. 80 W. Samples were collected from lacustrine silt and clay near the top of a roadcut.

Faunal list:	Pelecypods:	**Pisidium** sp.
	Gastropods:	**Valvata tricarinata**
		Lymnaea humilis
		Gyraulus parvus
		Helisoma anceps

Probable Environment: – Shallow lake. The presence of **Valvata** suggests a permanent, clear body of water. The other pulmonate snails, especially **H. anceps** support this idea despite their ability to live in environments not suitable to **Valvata. H. anceps**, as previously mentioned, is typical of rivers and streams in the Midcontinent, but has been found in lakes lacking inflowing or outflowing streams (Tuthill, and others, 1963). Thus its presence does not rule out a totally lacustrine environment of deposition for the sediments at this site. An alternative possibility is that inflowing streams carried shells of **H. anceps** into the environment of deposition after the death of the snails.

17. Hay Creek site: – The site is on the west side of a roadcut in the SE1/4 SE1/4 sec. 23, T. 139 N., R. 80 W. The samples were collected from unconsolidated, clean, outwash of fine to medium-grained sand at the crest of the bedrock knoll.

Faunal list:	Gastropods:	**Viviparus** sp.
		Catinella grosvenori gelida
		Succinea avara
		Discus cronkhitei

Probable Environment: – Stream bank or floodplain. All of the mollusks are terresetrial, except **Viviparus** sp. which I believe is a reworked Tongue River Formation and does not represent ecologic conditions at the time of deposition of these sediments.

Thus, total reliance on sedimentary evidence is required. The stream which laid down the sediments, must have passed through grassland or woods. All the snails are extant in North Dakota even in the areas where only prairie is found. The possibility that these sediments are of Recent age is not great, since streams capable of depositing outwash-type sediments do not now exist in the area.

18. Griffin Ranch site: – This site is in the south bank of a fresh, narrow, exposure in an east-west coulee, east side of the road in the NE1/4 SE1/4, sec. 27, T. 140 N., R. 81 W. Samples were collected from a very light gray marl, and light gray silt, with interbedded dark yellowish-orange medium to fine-grained sand overlain by two feet of wind blown soil.

Faunal list:	Pelecypods:	**Pisidium** sp.
	Gastropods:	**Gyraulus parvus**
		Lymnaea sp.
		Physa sp.
		Helisoma campanulatum
	Other Fossils:	**Chara? Oögonia and stems**
		Ostracod carapaces

Probable Environment: – Shallow lake. The presence of marl in the sediments virtually assures a limnitic environment, at least for that stratum, and strongly indicates that the entire sequence is a lacustrine deposit. The sand layers may indicate increased current or greater sorting due to wave action. The fauna is one typical of lakes, **H. campanulatum** being considered strictly a lake form.

19. Harvey Ranch site: – This site is in the north bank of Burnt Creek in the ditch on the east side of the road in the NW1/4, NW1/4, sec. 29, T. 140 N., R. 80 W. Samples were collected from sand and clay in an outwash channel.

Faunal list:	Gastropods:	**Vallonia gracilicosta**
		Vallonia sp. (juveniles)
		Gastrocopta armifera

Probable Environment: – Stream bank or floodplain. Both these taxa are typical of the long and short grass prairie biome in North Dakota today. They are capable of withstanding protracted periods of dry weather by sealing their aperture with a mucous epiphram. I have observed living specimens of **Succinea** estivating in joints in the terrace sediments of the Little Missouri River. If the snails were to die there, it is conceivable that they might be mistaken for fossils. If this habit is shared by **Gastrocopta** and **Vallonia**, this may explain their presence in these sediments. Kume suggests that the shells are Recent and while I found no living animals in them, I am inclined to think he is right.

20. Apple Creek site 1: – This site is on the north side of U. S.

Highway 10 about five miles east of Bismarck in the uppermost terrace of Apple Creek, in SW1/4 SW1/4, sec. 34, T. 139 N., R. 79 W. Samples were collected from the upper fifteen feet of very fine sand and silt sediments.

Faunal list: Gastropods:

Gyraulus parvus
Gyraulus sp.
Lymnaea humilis
Zonitoides arboreus
Catinella grosvenori gelida
Gastrocopta armifera (specimens destroyed during identifications)
Discus cf. D. cronkhitei
Vallonia gracilicosta

Probable Environment: – Stream bank or floodplain. The first three taxa are aquatic forms, but may occupy very unstable environments. Because of a large number and variety of land snails, I believe the sediments to be redistributed stream deposits, the fossil content of which was enriched by resident and nearby terrestrial snails. Wind may well have been the agent of transportation as sand dunes are known in the area.

21. Johnson Ranch site: – The site is in the NW1/4 NW1/4 sec. 11, T. 140 N., R. 80 W. The fossils came from sand deposits along the north edge of the floodplain of Burnt Creek.

Faunal list: Gastropods:

Discus cronkhitei
Succinea cf. S. avara

Probable Environment: – Stream bank or floodplain. I believe that these specimens are from a fauna of Recent Age. Both species are known in Grant County to the southwest and they are no doubt also resident in Burleigh County. Stream valleys are a normal environment of these species in North Dakota today.

22. Haberlin Ranch site: – The site is in the NW corner of section 35, T. 143 N., R. 79 W. Lacustrine marls, silts and clays overlying till comprise the lithology of this site. These deposits lie approximately two miles beyond the distal side of the Burnstad dead-ice moraine of north and northeastern Burleigh County.

Faunal list: Gastropods:

Valvata tricarinata
Valvata lewisi
Gyraulus parvus
Helisoma sp.
Lymnaea humilis
Promenetus exacuous

Pelecypods:

Pisidium sp.

Probable Environment: – Shallow lake.

23. Blackman Ranch site: — The site is located in the SW1/4 NW1/4 sec. 30, T. 143 N., R. 79 W., three miles beyond the distal side of the Burnstad dead-ice moraine in sheet moraine of the Napoleon Drift. The samples were collected from lacustrine sand and silt overlying till.

Faunal list:	Gastropods:	**Valvata lewisi** **Lymnaea humilis** **Gyraulus parvus** **Succinea cf. S. avara** **Vallonia** sp. **Zonitoides arborea**

Probable Environment: — Shallow lake. The land snails **S. avara, Vallonia** sp., and **Z. arborea** are minor elements of the fauna from this site. **V. lewisi** is a lake form of this genus. The high silt and sand content of these sediments is probably indicative of an environment of deposition near shore in a clear lake rather than of fluviatile inlets. The land snails were probably blown into the lake and the aquatic snails probably resided in the immediate vicinity. Thus a clear lake is indicated with abundant aquatic and border vegetation.

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TABLE 5 – Species composition of the Molluscan faunules by sites in Burleigh County. See text for locations of sites, listed here by number.

Mollusks	Missouri Coteau Sites										Coteau Slope Sites													No. of
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Occurrence
PELECYPODS																								
Naiad frags.					x																			1
Sphaerium spp.	x							x			x	x		x										5
Pisidium spp.		x		x	x		x	x	x	x		x	x			x		x				x		12
GASTROPODS																								
Viviparus sp.															x		x							2
Valvata tricarinata		x	x	x	x	x	x	x	x	x	x					x						x		12
V. lewisi																						x	x	2
Amnicola limosa		x	x	x		x	x	x		x	x	x												9
Lymnaea palustris													x											1
L. humilis			x				x							x		x				x		x	x	7
L. stagnalis														x										1
Lymnaea sp.				x	x	x												x						4
Gyraulus parvus	x	x	x	x	x		x	x		x		x	x	x		x		x		x		x	x	16
Gyraulus sp.	x			x	x	x	x	x	x	x										x				9
Promenetus exacuous			x	x		x	x	x		x			x									x		8
Armiger crista					x			x		x			x											4
Helisoma trivolvis											x		x											2
H. campanulatum			x			x	x	x										x						5
H. anceps		x	x		x		x	x		x		x				x								8
Helisoma sp.																						x		1
Physa cf. P. gyrina								x																1
Physa sp.												x		x				x						3
Gastrocopta armifera																			x	x				2
Pupilla blandi															x									1
Vallonia gracilicosta															x				x	x				3
Vallonia sp.																			x				x	2
Catinella grosvenori															x									1
C. g. gelida																	x			x				2
Succinea avara																	x				x		x	3
Discus cronkhitei															x		x			x	x			4
Zonitoides arborea																				x			x	2
Number of species in each faunule	3	5	7	7	8	6	9	11	3	8	4	6	6	5	5	5	4	5	3	8	2	7	6	133

14 Species found in the Missouri Coteau District Faunules.

23 Species found in the Coteau Slope District Faunules.