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GEOLOGY AND GROUND WATER RESOURCES WILLIAMS COUNTY, NORTH DAKOTA

PART I – GEOLOGY

by
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Prepared by the North Dakota Geological Survey in cooperation with the North Dakota State Water Commission, United States Geological Survey, and Williams County Board of Commissioners.

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ILLUSTRATIONS

TABLES

THE GEOLOGY

OF WILLIAMS COUNTY

by

Theodore F. Freers

ABSTRACT

Williams County, in northwestern North Dakota, is located near the center of the structural and sedimentary Williston basin. The preglacial sedimentary formations beneath the county are as much as 14,828 feet thick. Their beds dip generally to the south except along the flanks of the north-south striking Nesson anticline in the eastern part of the county. Late Wisconsinan glacial deposits cover all of Williams County except along the Missouri River and other scattered small areas.

Topography of glacial origin includes knob and kettle, dissected upland, level upland, intraupland flats, and parts of bottomland. Badland topography and part of the bottomland topography are of nonglacial origin. Surficial deposits are chiefly glacial till and outwash with some areas of Tertiary Tongue River and Sentinel Butte Formations. The thickness of the glacial deposits on uplands ranges from a few feet in the southern part of the county to more than 100 feet in the northern part of the county. Thick glacial deposits occur in the preglacial Yellowstone and Little Missouri River valleys. These two partly buried valleys contain thick deposits of silt, sand, and gravel. At several locations beneath the glacial deposits, small outcrops of the nonglacial Wiota Gravel of western and southwestern origin occur.

Advancing Pleistocene glaciers modified the preglacial valley and divide topography and diverted the northward-flowing rivers to easterly courses. Two advances of glacier ice were recognized in southern Williams County, but no evidence for drift older than late Wisconsinan was found.

Petroleum, the most important resource in the county, is produced mainly from the Mississippian Madison Formation along the Nesson anticline. Sand, gravel, lignite, "scoria," and salt are currently being mined in the county.

INTRODUCTION

Purpose

This geological report of Williams County, North Dakota, is part of a cooperative groundwater project by the North Dakota Geological Survey, the North Dakota State Water Commission, and the United States Geological Survey. In addition to this report, a compilation of ground-water basic data (Part II) and a report of the hydrology (Part III) of Williams County has been published. Glacial drift and exposed bedrock were the primary subjects of the field work and are emphasized in this report.

The main objectives of this investigation were to compile a geologic map of Williams County, to recommend locations for ground-water test holes, to look for potentially economic geological resources, and to explain the geological processes involved in shaping the geology of the area.

Sources of Information

FIELD METHODS

Williams County (pl. 1) was mapped by Jack Kume, Dan E. Hansen, and Theodore F. Freers of the North Dakota Geological Survey during the summer and fall of 1963, and the bedrock was studied during the summer and fall of 1964 by Theodore F. Freers and John P. Bluemle and during the spring and early summer of 1965 by Freers. Information gathered in the field was plotted on a 1960 Williams County highway map, scale 1:63,360. Topographic map coverage in Williams County includes all of the Grenora, Hanks, Zahi, Marmon SE, Williston West, and Williston East and part of the Brush Lake quadrangles (7 1/2 minute series, scale 1:24,000) and part of the Ray quadrangle (30 minute series, scale 1:125,000), all published by the U. S. Geological Survey. Aerial photograph stereopairs (scale approximately 1:20,000, flown in 1958) were used for reconnaissance and to refine the contacts between geological units. The mapping procedure consisted of lithologic determinations of the near-surface material at selected intervals along all the accessible section lines. Additional information was gathered on foot in the areas where driving was not possible or where more detail was needed.

Bedrock lithologies were determined while measuring vertical sections at selected locations. All color codes given in this report are from the Rock Color Chart (Goddard and others, 1951). Subsurface investigations of the glacial drift by the U. S. Geological Survey and the North Dakota Water Commission using rotary drill rigs provided additional information which is used in this report.

Sub-Tongue River Formation stratigraphy is briefly discussed using information available from oil well cores, cuttings, and mechanical logs.

Acknowledgments

Dr. Wilson M. Laird was particularly helpful while visiting the writer and other geologists in the field where he contributed many useful ideas. Jack Kume and Dan Hansen mapped large areas of Williams County (pl. 1), and John P. Bluemle helped measure bedrock sections along the Missouri River.

Clarence Armstrong, author of Parts II and III of this study, gave many valuable suggestions. The geologists of the North Dakota State Water Commission, L. L. Froelich, Alain Kahil, and Roger Schmid provided geologic and mechanical logs of all the test holes drilled during the study. The cooperation of the Williams County Board of Commissioners is also greatly appreciated.

I also wish to thank Lee Clayton of the Department of Geology at the University of North Dakota for reviewing and editing this report and Henry Reed, geologist with The Great Northern Railroad, for the contribution of his information on Williams County. Sidney B. Anderson, head of the North Dakota Geological Survey Subsurface Division, helped with the pre-Tertiary stratigraphy. I appreciate the contributions of these agencies and individuals during this study.

Geologic Setting

Williams County, an area of 2,032 square miles in northwestern North Dakota (fig. 1), lies in the glaciated section of the Missouri Plateau of the Great Plains Province (Fenneman, 1931). To the northeast of the area of study is the Missouri Coteau, a band of

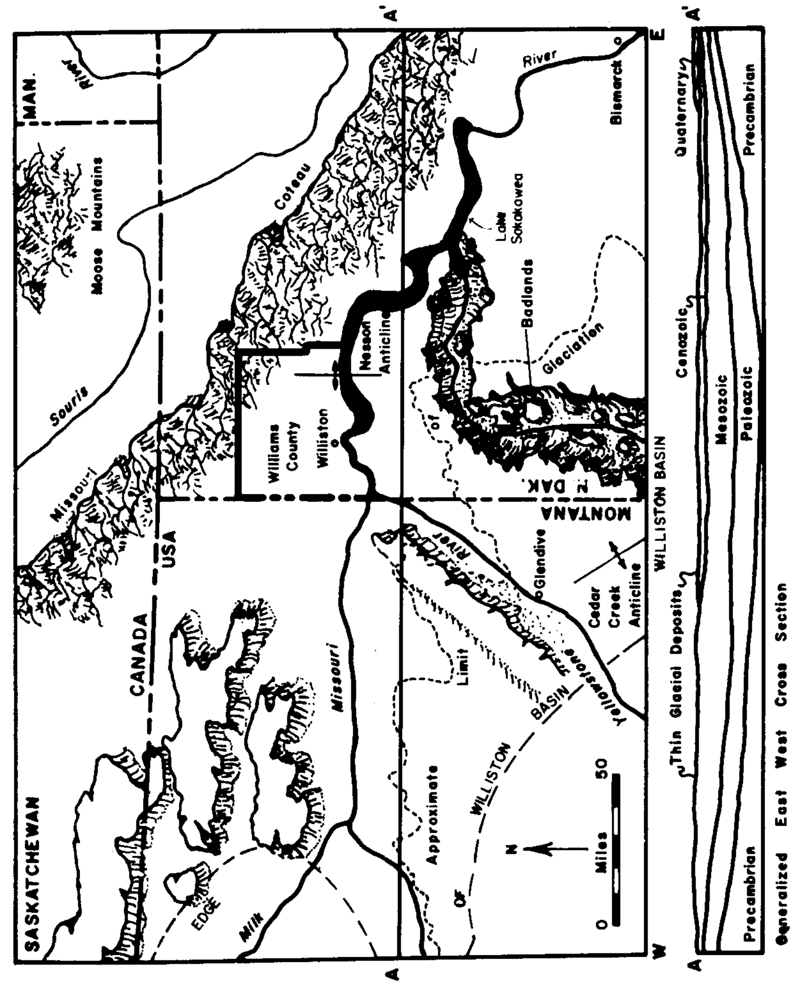

FIGURE 1. Schematic drawing of major regional physiographic and geologic features of Williams County and adjacent areas.

morainic hills 30 to 40 miles wide and extending from South Dakota into Saskatchewan. In the area of study, the Missouri Coteau is the continental divide between the Gulf of Mexico and Hudson Bay. Northeast of the Missouri Coteau are the plains of the Central Lowland Province.

South of Williams County, the glacial deposits are thin and scattered for 40 to 50 miles to the limit of glaciation (fig. 1). South of the limit of glaciation, the badlands are incised into the Paleocene Tongue River and Sentinel Butte Formations, and occasional buttes are capped by Eocene Golden Valley and/or Oligocene White River Formation beds.

West of Williams County are relatively thin glacial deposits. Within the glaciated region to the west are large exposures of Tertiary and some Cretaceous deposits. The plateaus northwest and west of Williams County are capped by the Flaxville Gravel.

Beneath the glacial deposits in the region are Late Mesozoic and Early Tertiary beds. This area lies within the Williston basin (fig. 1, cross-section) with sediments as much as 15,128 feet thick, representing every period from the Cambrian to the present (Carlson and Anderson, 1965).

SURFACE TOPOGRAPHY

Lemke and Colton (1958, fig. 1), Clayton (1962, p. 14), and Kume and Hansen (1965, p. 7-8) have subdivided the areas of the Missouri Plateau north and east of the Missouri River into the Coteau du Missouri (or Missouri Coteau), the Coteau Slope, and the Missouri River Trench (fig. 2). These physiographic subdivisions are usable on a regional basis; but in the investigation of Williams County, it was found that there was more similarity between some of the subdivisions than within each subdivision. A study of the topographic features has resulted in the establishment of nine topographic (physiographic) units within Williams County.

Elevations in Williams County range from about 1,840 feet to over 2,500 feet. There are two large low areas, the Missouri River bottomlands, along the southern edge of Williams County, and the Little Muddy River valley, 3 to 4 miles wide, trending from Williston north to the Divide County line (fig. 2). North of the Missouri River bottomlands and on either side of the Little Muddy River valley, the land rises to an upland at an elevation of 2,200 to 2,400 feet. The

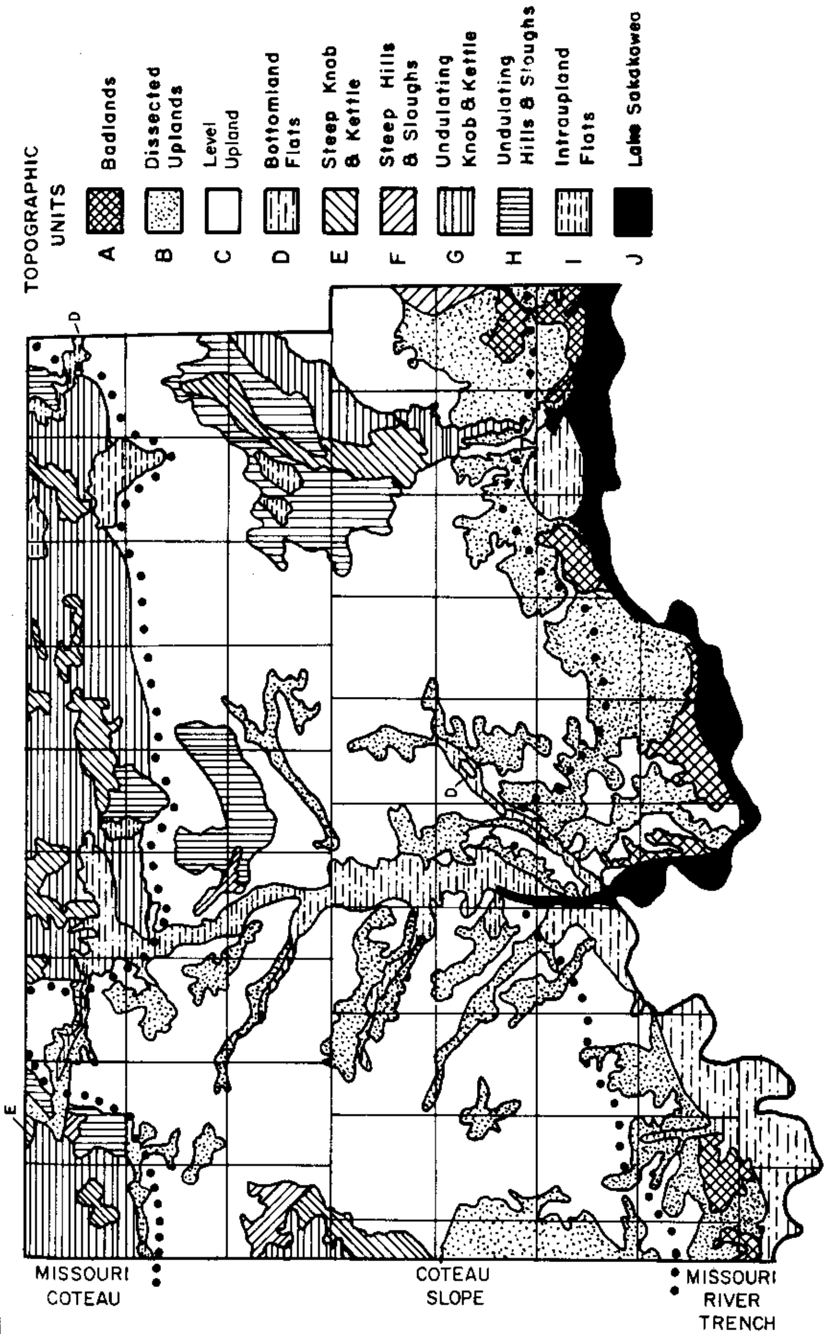

FIGURE 2. Topographic units of Williams County.

TABLE 1. Topographic Units of Williams County

Unit	Drainage	Slope: Type[1]	Slope: Degrees	Local relief[2]	General Name
A	Integrated	Steep	20-65	High (greater than 50 feet)	Badland
B	Well integrated	Hilly and steep	5-20	Medium (15 to 50 feet) to high (greater than 50 feet)	Dissected upland
C	Fairly well integrated	Undulating to rolling	3-10	Low (5 to 15 feet) to medium (25 to 50 feet)	Level upland
D	Well integrated	Nearly level	0-2	Low (less than 15 feet)	Bottomland
E	Nonintegrated	Hilly and steep	5-20	Medium (15 to 50 feet) to high (greater than 50 feet)	Steep, knob, and kettle
F	Nonintegrated	Hilly and steep	5-20	Low (0 to 15 feet) to medium (15 to 50 feet)	Steep, hilly, and sloughy
G	Partly integrated	Undulating to rolling	3-10	Medium (15 to 50 feet) to high (greater than 50 feet)	Undulating knob and kettle
H	Partly integrated	Undulating to rolling	3-10	Low (0 to 15 feet) to medium (15 to 50 feet)	Undulating, hilly, and sloughy
I	Partly integrated	Nearly level	0-2	Low (0 to 15 feet)	Intrauplan flat

[1]Modified from USDA Soil Survey Manual p. 162 to 164. (Soil Survey Staff, 1951)
[2]Local relief based on estimated elevation difference between adjacent lows and highs.

bottom of many valleys, tributary to the Missouri River and Little Muddy River, are at elevations of 1,900 to 2,000 feet. Another low area below 2,000 feet is west of Grenora in extreme northwestern Williams County.

Topographic Units

Topographic units are determined in Williams County by combinations of degrees of drainage integration, local relief and average slope angles.

Drainage integration was determined in the field and from aerial photographs and was found to be nonintegrated, partly integrated, fairly well integrated, and integrated. There are no abrupt boundaries between the different degrees of drainage integration, and partly integrated and fairly well integrated overlap considerably. Local relief was determined in the field by estimating the elevation differences between adjacent lows and highs. Three terms are applied to local relief--low (0 to 15 feet), medium (15 to 50 feet) and high (greater than 50 feet). Slope was determined primarily in the office using a reconnaissance soils map of Williams County (General Soil Map, Williams County; prepared by the North Dakota Agricultural Experiment Station, Department of Soils, scale 1:126,720). Slope types and angles were taken from the soils map and regrouped into a form usable for delineating topographic units. Slope types are steep (20^o to 65^o), hilly and steep (5^o to 20^o), undulating to rolling (3^o to 10^o), and nearly level (0^o to 2^o). Combinations of drainage integration, local relief, and slope angles are used on the topographic unit map Figure 2 and in Table 1.

TOPOGRAPHIC UNIT A (BADLAND)

This area is characterized by badland topography. It has 20^o to 65^o slopes, usually the higher angles, integrated drainage, and usually high local relief, up to 500 feet. Unit A is found almost entirely on the Tongue River and Sentinel Butte Formations and has slopes almost devoid of plant life. Erosion of the badland topography has resulted in sharp, almost knife-like ridges, with steep arroyos between Steep rills and resistant ledges are common. The few buttes that are present are generally capped by glacial drift overlying a resistant sandstone or a siliceous bedrock layer. Large slump blocks as much as 1/4 mile long occur at several locations.

Topographic Unit A is found almost entirely along the Missouri River, except for three small areas, one near Hanks in northwestern Williams County, one along Stony Creek, northeast of Williston and an area west of Williston on the Montana state line. These three small areas are not shown on Figure 2.

TOPOGRAPHIC UNIT B (DISSECTED UPLAND)

Unit B consists of well integrated hilly topography with hilly and steep (5° to 20°) slopes and medium (15 to 50 feet) to high (greater than 50 feet) local relief. It is primarily a dissected upland consisting of valleys between relatively level uplands; it consists of bedrock overlain by a blanket of glacial deposits. The largest area of Unit B is found in the Missouri River Trench between Unit A, badlands, and Unit C, level uplands. Other areas of Unit B are found along the major streams of Williams County.

TOPOGRAPHIC UNIT C (LEVEL UPLANDS)

This is an upland area and is found at elevations of 2,210 to 2,400 feet. It has fairly well integrated drainage on undulating to rolling slopes of 3° to 10° and has mostly low relief. The area of Unit C is largely on the Coteau Slope with a few areas within the Missouri River Trench. Unit C is underlain almost entirely by glacial drift deposits. It is essentially a gently rolling plain with a few undrained depressions and a few ridges of glacial origin. There are some broad valleys with low slopes occurring on the valley walls. Integration of drainage is almost complete, but very recent.

TOPOGRAPHIC UNIT D (BOTTOMLAND)

Unit D is characterized by flat bottomland topography. It has fairly well integrated drainage, nearly level slopes (0° to 2°) and low relief (0 to 15 feet). It consists of floodplains of the Missouri River and tributary streams and by gravel and sand terraces in the Little Muddy River valley. Unit D lies at elevations from about 1,850 to 2,050 feet. Commonly Unit D is nearly flat, especially along the Missouri River, but near the Divide County line the topography is gently rolling and pitted in places. The slope of this unit increases from the floodplain of

the Missouri River to as much as 4° to 5° on the tributary valleys. Unit D is underlain by mixtures of clays, silts, sands, and gravels.

TOPOGRAPHIC UNIT E (STEEP KNOB AND KETTLE)

Unit E is characterized by high relief, knob and kettle topography, medium (25 to 50 feet) to high (greater than 50 feet) local relief, hilly and steep slopes (5° to 20°), and nonintegrated drainage. Of all the topographic units, Unit E has the least integrated drainage. The slope angles have a considerable range within a short distance. The tops of some of the knobs are nearly level, whereas the side slopes are about 20°, except the lower 10 feet near sloughs or kettles, where the slope may be as much as 35°. Most slough bottoms are nearly level. Unit E covers only small isolated areas in the north and east sides of Williams County. North in Divide County are large areas of this knob and kettle topography. This topographic unit is entirely underlain by glacial drift. There is some integrated drainage within the area of Unit E, but it is limited to the land immediately adjacent to glacial channels.

TOPOGRAPHIC UNIT F (STEEP HILLS AND SLOUGHS)

This unit is identical to Unit E, but has low (5 to 15 feet) to medium (15 to 50 feet) local relief. The topography is characterized by medium relief and hilly and sloughy features. Drainage is nonintegrated although there are some narrow channels which transect some of Unit F. In general, the area has low knobs and undrained sloughs underlain everywhere by glacial till. There are some ridges, but the topography is predominantly irregular or nonlineal.

TOPOGRAPHIC UNIT G (UNDULATING KNOB AND KETTLE)

This unit has partly integrated drainage, medium (15 to 50 feet) to high (greater than 50 feet) local relief, and undulating to rolling (3° to 10°) slopes. The primary difference between Unit E and Unit G is that Unit G has lower slopes and more medium local relief, whereas Unit E has higher slopes and higher local relief. Slough banks are more gentle in Unit G than in Unit E. Unit G areas are underlain by glacial till.

	SYSTEM	SEQUENCE	GROUP OR FORMATION		DOMINANT LITHOLOGY
CENOZOIC	TERTIARY	TEJAS	GLACIAL DEPOSITS		Sandy loam, Sand and Gravel
			WHITE RIVER		Clay, Sand, and Limestone
		ZUNI	GOLDEN VALLEY		Clay, Sand and Silt
			FORT UNION GROUP	SENTINEL BUTTE	Shale, Clay, Sandstone and Lignite
				TONGUE RIVER	Shale, Sandstone and Lignite
				CANNONBALL-LUDLOW	Marine Sandstone and Shale
MESOZOIC	CRETACEOUS		HELL CREEK		Sandstone, Shale and Lignite
			MONTANA GROUP	FOX HILLS	Marine Sandstone
				PIERRE	Shale
			COLORADO GROUP	NIOBARA	Shale, Calcareous
				CARLILE	Shale
				GREENHORN	Shale, Calcareous
				BELLE FOURCHE	Shale
			DAKOTA GROUP	MOWRY	Shale
				NEWCASTLE	Sandstone
				SKULL CREEK	Shale
				FALL RIVER	Sandstone and Shale
				LAKOTA	Sandstone and Shale
	JURASSIC		MORRISON		Shale, Clay
			SUNDANCE		Shale and Sandstone
			PIPER		Limestone, Anhydrite, Salt and red Shale
	TRIASSIC	ABSAROKA	SPEARFISH		Siltstone, Salt and Sandstone
PALEOZOIC	PERMIAN		MINNEKAHTA		Limestone
			OPECHE		Shale, Siltstone and Salt
	PENNSYLVANIAN		MINNELUSA		Sandstone and Dolomite
			AMSDEN		Dolomite, Limestone, Shale & Sandstone
	MISSISSIPPIAN	KASKASKIA	BIG SNOWY GROUP	HEATH	Shale,
				OTTER	Sandstone and
				KIBBEY	Limestone
			MADISON		Interbedded Limestone and Evaporites
					Limestone
			BAKKEN		Siltstone and Shale
	DEVONIAN		THREE FORKS		Shale, Siltstone and Dolomite
			BIRDBEAR		Limestone
			DUPEROW		Interbedded Dolomite and Limestone
			SOURIS RIVER		Interbedded Dolomite and Limestone
			DAWSON BAY		Dolomite and Limestone
			PRAIRIE		Halite
			WINNIPEGOSIS		Limestone and Dolomite
	SILURIAN	TIPPECANOE	INTERLAKE		Dolomite
			STONEWALL		Dolomite and Limestone
	ORDOVICIAN		STONY MOUNTAIN FORMATION	GUNTON MEMBER	Limestone and Dolomite
				STOUGHTON MEMBER	Argillaceous Limestone
			RED RIVER		Limestone and Dolomite
			WINNIPEG GROUP	ROUGHLOCK	Calcareous Shale and Siltstone
				ICEBOX	Shale
				BLACK ISLAND	Sandstone
	CAMBRIAN	SAUK	DEADWOOD		Limestone, Shale and Sandstone
	PRECAMBRIAN				

FIGURE 3. Stratigraphic column of North Dakota.

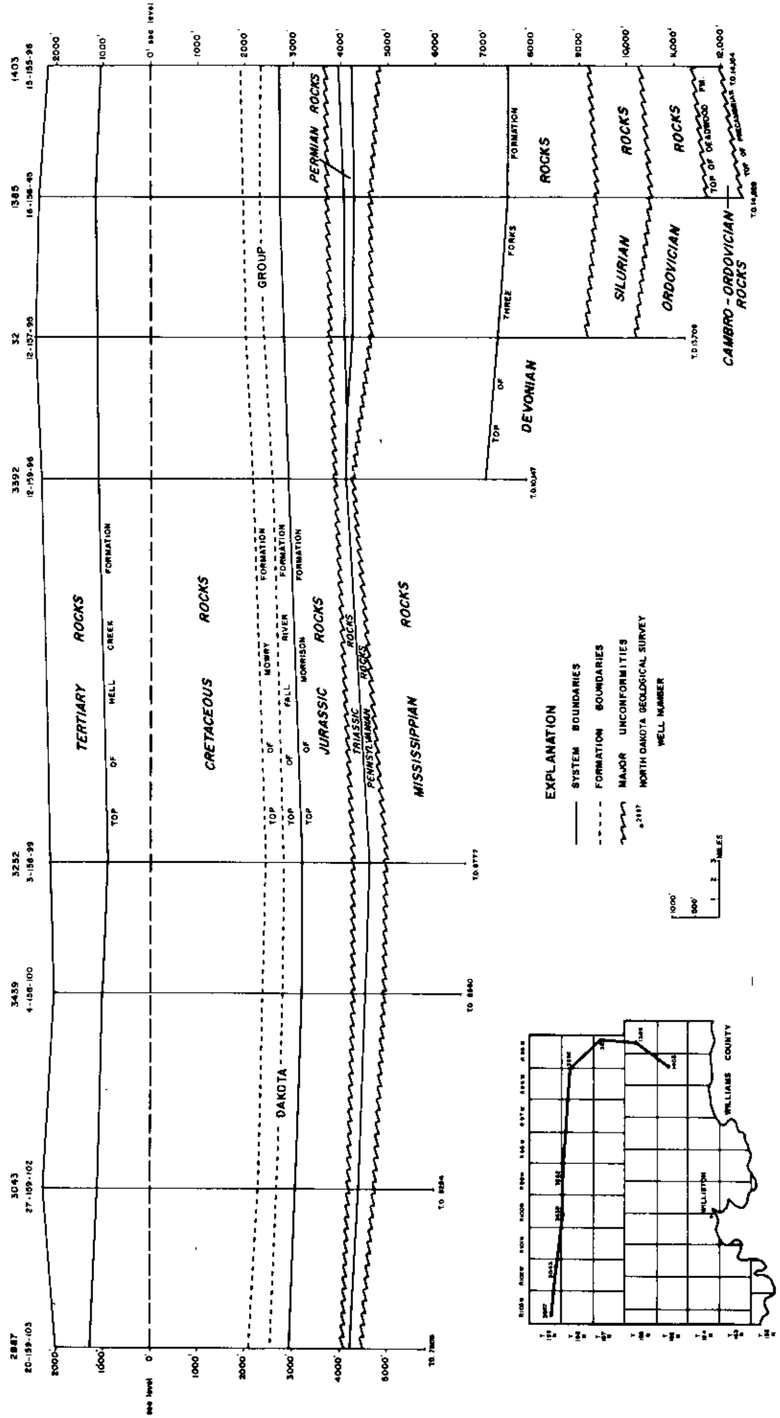

FIGURE 4. Stratigraphic cross section from northwestern to southeastern Williams County.

TOPOGRAPHIC UNIT H (UNDULATING HILLS AND SLOUGHS)

This unit is characterized by areas of low (5 to 15 feet) to medium (15 to 50 feet) local relief, undulating to rolling (3^{o} to 10^{o}) slopes, and partly integrated drainage. Although this unit is similar to the previous three hilly and sloughy units, its outward character is subtle because it has low hills and low undrained depressions. It is most easily recognized on aerial photographs. Unit H is underlain by glacial drift, chiefly glacial till.

TOPOGRAPHIC UNIT I (INTRAUPLAND FLATS)

Unit I consists of intraupland flats. The features of this unit include partly integrated drainage, low (0 to 15 feet) local relief, and nearly level (0^{o} to 2^{o}) slopes. Unit I in Williams County is underlain by clays and silts. This unit is associated with Units E to G (hilly and sloughy types).

SUMMARY OF THE PRE-TERTIARY STRATIGRAPHY

Williams County lies near the center of the intracratonic Williston basin (fig. 1), which is a structural and sedimentary basin. The greatest known thickness of post-Precambrian sediments in the Williston basin is 15,128 feet in a well in McKenzie County. The deepest well in Williams County was drilled to a depth of 14,828 feet along the Nesson anticline (fig. 1). Most wells in the county have been drilled into the upper Paleozoic rocks along the Nesson anticline and in the Grenora field in northwestern Williams County.

The oldest exposed rocks are those of the Tertiary Tongue River and Sentinel Butte Formations. Data on the older rocks (fig. 3) comes from mechanical well logs, cores, and drill cuttings. Figure 4, a cross-section along the Nesson anticline and then west to the Grenora field, shows the stratigraphic relationship of the formations in the county.

Precambrian Rocks

Three oil wells have been drilled into the Precambrian. In two of them, syenite was identified as the Precambrian rock-type; the third

well probably had weathered syenite. Above the Precambrian rocks are six sequences separated by five major unconformities (fig. 3) (Carlson and Anderson, 1965).

SAUK SEQUENCE

The Sauk Sequence in Williams County consists of the Cambro-Ordovician Deadwood Formation. The Deadwood Formation lies unconformably on the Precambrian and is composed of limestone, shale, and sandstone.

TIPPECANOE SEQUENCE

The Tippecanoe Sequence includes most of the Ordovician and all of the Silurian systems. The Winnipeg Group, at its base, consists of sandstone, siltstone, and shale. Overlying the Winnipeg Group is the Red River, Stony Mountain, Stonewall, and Interlake Formations which are limestones and dolomite. Oil and gas is produced from this sequence.

KASKASKIA SEQUENCE

Many formations are found in this sequence which include all of the Devonian and Mississippian systems. The lithologies within the Kaskaskia Sequence are predominantly limestone and dolomite with some evaporites, siltstones, and sandstones. In the Upper Kaskaskia Sequence is the Madison Formation which produces most of the oil and gas in North Dakota.

ABSAROKA SEQUENCE

The Absaroka Sequence includes all of the Pennsylvanian, Permian, and Triassic systems. This sequence has five formations that are composed of sandstone, siltstone, shale, limestone, dolomite, and salt.

ZUNI SEQUENCE

The Zuni Sequence includes all of the Jurassic and Cretaceous systems and part of the Tertiary system. It includes both marine and non-marine beds consisting of sandstones, shale, limestone, anhydrite, salt, lignite, clay, and silt. This sequence includes the vast lignite resources of the Tongue River and Sentinel Butte Formations. The Golden Valley Formation in Figure 3 is not known to be present in Williams County.

TEJAS SEQUENCE

The White River Formation is found in this sequence but is not known to be present in Williams County. The glacial deposits are the only major deposits represented in the Tejas Sequence. The Tejas Sequence extends to the present time. The lithologies of the Tejas Sequence are primarily sandy clay, sand, and gravel.

TERTIARY DEPOSITS

Cannonball and Ludlow Formations

The Fort Union Group, which is of Paleocene age in North Dakota (Brown, 1962) consists of the Ludlow, Cannonball, Tongue River, and Sentinel Butte Formations. The lowermost Tongue River, Cannonball and Ludlow Formations are not exposed in Williams County but come close to the surface along the Nesson anticline. The Cannonball and Ludlow Formations are interfingering sand and shale deposits with some lignite in the Ludlow in other areas of North Dakota, but little is known of these formations in Williams County.

Tongue River and Sentinel Butte Formations

Directly beneath the Recent and Pleistocene deposits in Williams County are the Tongue River and Sentinel Butte Formations. These formations were first investigated by Meek and Hayden (1862) who described the beds exposed on the north side of the Missouri River near Fort Union (pl. 1) on the North Dakota-Montana border; they called these beds the Fort Union Group. The Tongue River Formation was first described by Taff (1909) along the Tongue River in the Sheridan Coal Field, Wyoming, and was later traced into North Dakota by Thom and Dobbin (1924). Leonard (1908) named the upper part of the sequence at Sentinel Butte, North Dakota, the Sentinel Butte Formation. The exposed bedrock in Williams County is the Sentinel Butte Formation with the exception of some Tongue River beds exposed on the crest and east flank of the Nesson anticline (pl. 3) and the beds west of T. 102 W. along the Missouri River (Royse, 1967).

Exposures of the Fort Union Group in Williams County are found along the Missouri River and many of its tributaries, along Scoria Creek at Hanks, at Bull Butte in T. 156 N., R. 104 W., and at many other isolated, small exposures shown on Plate 1. The bedrock exposures in places are over 400 feet high along the Missouri River (for example, measured sections 21 and 22 in pl. 3), but in others they are only a few feet high. Twenty-eight separate sections were measured between the Williams-Mountrail County line and Snowden, Montana. These twenty-eight sections, some of which are represented in the stratigraphic cross-section Plate 3, included lithologic descriptions, thickness, and structure.

BEDROCK TOPOGRAPHY

The topography on top of the Fort Union beds is basically similar to the present surface topography. A major low (pl. 2) that trends north from Williston to the Divide County line may be an old course of the Yellowstone River. This low is at an elevation of about 1,700 feet, except in the northern part of the county where it drops to 1,600 feet. East and west of the low the bedrock rises to a 2,000 foot to 2,300 foot up land. Another low area that bisect the upland to the east may be the old course of the Little Missouri River. Small lows that head back from the old Yellowstone River valley are probably preglacial tributary valleys. West of Grenora, an area below 1,700 feet is probably part of the old course of the Missouri River. Two large highs in T. 156 N., R. 104 W., and T. 158 N., R. 95 W., are probably large buried preglacial buttes.

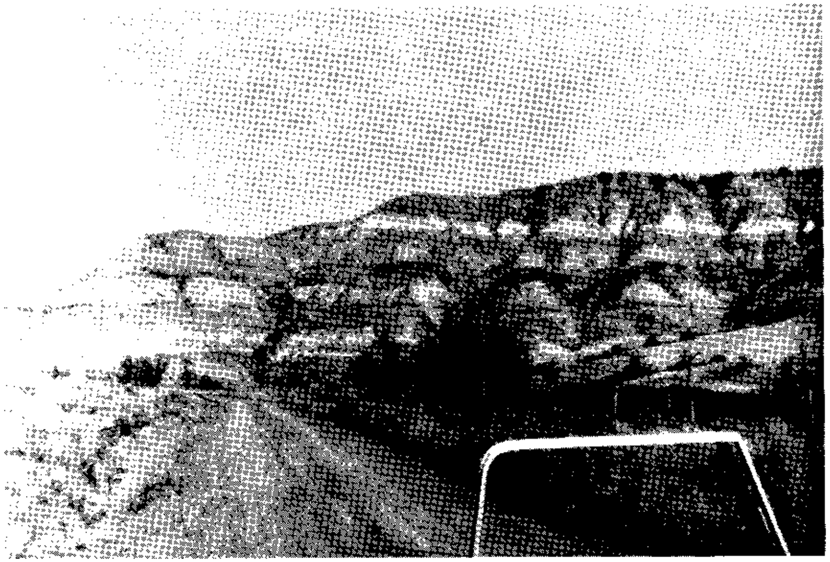

FIGURE 5. Tongue River Formation where the Missouri River cuts across the Nesson anticline in southeastern Williams County.

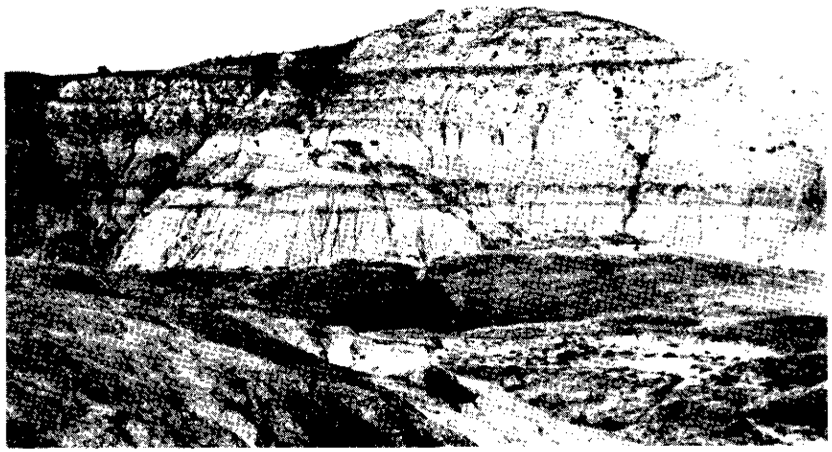

FIGURE 6. Sentinel Butte Formation along the Missouri River in the NE 1/4 sec. 20.,T. 153 N., R. 99 W.

The Sentinel Butte Formation consists of alternating beds of somber-colored clays, silts, sands, and lignites (fig. 6). The Tongue River Formation is similar but is lighter and more yellow (fig. 5). No estimates are made of the abundance of any lithologies because of the diverse character of the formation. However, clay and shale are probably the most abundant.

Sand and sandstone

Thickness of sand and sandstone beds ranges from several inches to over 90 feet. Almost every measured section contained some sand, which is found everywhere in the area of study. Commonly, the tops of buttes are capped by sandstone that is more resistant to weathering than the other beds of the Tongue River Formation. These beds do not persist laterally over great distances, and often they pinch out in a few hundred feet.

The sand in weathered outcrops is generally yellowish gray (5Y 7/2) to light gray (N7) with rust-colored stains. The sandstone is yellowish gray (5Y 7/2) or yellowish gray (5Y 8/1). The sand is fine to medium grained and the sandstone is very fine to medium grained. No beds with larger than medium-sized particles were seen with the exception of some conglometric-claystone channel deposits. All sand grains that were examined are subangular. Sorting ranges from clayey sand to silty sand to sand.

Bedding of the sand is most easily seen in the wind-eroded sandstones (fig. 7). Most of the sandstone is cross-bedded with some foreset and topset beds. Bedding in sand that is not well indurated generally appears to be horizontal and often obscure. Most of the sands are massive, non-indurated, clean, and uniform with claystone or ironstone layers.

The most common secondary features in the sand are concretions. Spherical limonite concretions are common. They are as much as 8 inches in diameter, and their iron oxides stain the surface of the sand a yellowish brown (10YR 5/3), and sometimes contain centers of unweathered marcasite. Another kind of concretion is a log-like cylinder. These are hard, well-indurated cylinders of cross-bedded sand 2 or 3 feet in diameter and sometimes several hundred feet long. They are usually much harder than the surrounding sand.

Fossils are present in some of the sand, but none were found in the sandstone. The most common fossils in the sands are twigs or leaf imprints. Gastropod and pelecypod shells are sometimes found.

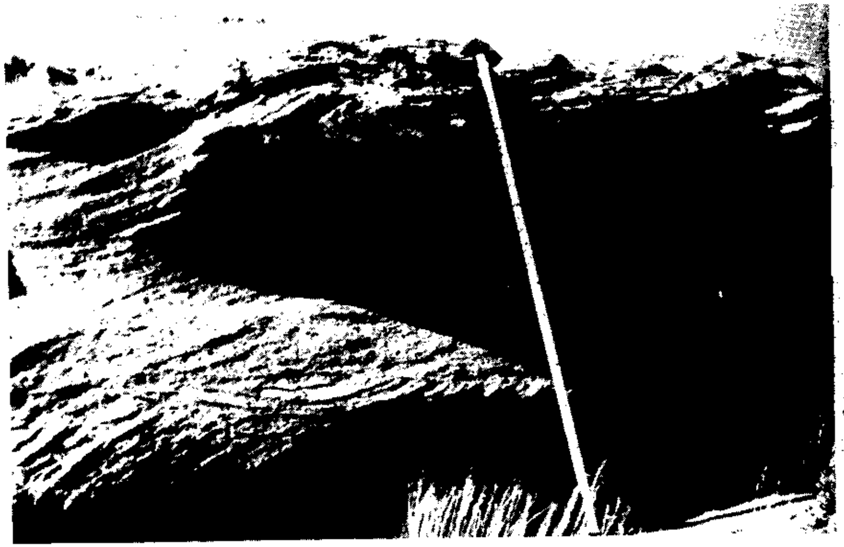

FIGURE 7. Wind-eroded, cross-bedded sandstone of the Sentinel Butte Formation, SE 1/4 SW 1/4, sec. 16, T. 153 N., R. 99 W.

Silt

Silt is present in the Sentinel Butte Formation throughout the area of study. Silt beds range in thickness from several inches to more than 30 feet, but most are less than 10 feet thick. The silt beds commonly grade laterally to different lithologies such as clays or sands within a few tens of feet.

The silts are commonly yellowish gray (5Y 7/2) and less commonly light olive gray (5Y 5/2) on weathered outcrops. Some silt beds are very conspicuously grayish yellow (5Y 8/4), much yellower than most adjacent beds.

Sorting of the silts is variable. Most of those described in the measured sections in Plate 3 contain some clay. A large proportion of the silts contain very fine sand. Silt grains are angular. The silts are usually bedded, individual beds being less than one millimeter thick.

The silt is very poorly cemented and is soft and loose. A large percentage of the beds are calcareous in the weathered zone (about [illegible] feet into the outcrop). In general, the silt beds are massive, clean, and uniform; but carbonaceous streaks occur on some of the bedding planes. In addition, limonite balls and other concretions are common. Also found in the silt are gypsum crystals, selenite, and ironstone layers. A few of the beds contain plant fossils, gastropods, and pelecypods.

Clays, claystone, and shales

The term clay, in this report, refers to soft,bedded or unbedded clays; claystone, hard, unbedded, massive clays; and shale, hard, bedded or fissile clays.

Clays, silty clays, sandy clays, claystone, and shale are the most extensive lithologies in the exposed Fort Union beds of Williams County. Some of the beds are only a fraction of an inch thick while others are nearly a hundred feet thick.

Like the sand and silt, the clays and shales have little lateral persistence over great distances. They are more persistent than the other mentioned lithologies, but they may pinch out in several hundred feet or grade to another lithology. Some of the underclays beneath the lignites are as persistent as the lignite bed under which they lie.

The clay and claystone is commonly yellowish gray (5Y 7/2) or light olive gray (5Y 5/2). Less commonly it is very light gray (N8),or dark gray (N4), and sometimes olive brown (5Y 4/4), olive black (5Y 2/1), or dusky yellow (5Y 6/4). Shales are not as common as the clays and claystone. They range from grayish red (5R 4/2) to light olive gray (5Y 5/2). The clay beds in deep fresh cuts are darker than on weathered surfaces; examples are dusky yellow green (5GY 5/2) or dark yellowish orange (10YR 6/6).

Sorting of the clays and claystones varies from nearly pure clay to silty and sandy clay; the shales are largely composed of clay-size material. Bedding is evident in the shales and some of the clays. The claystones are massive, hard and sometimes have a sub-conchoidal fracture. Carbonaceous shales are well bedded and fissile. The clays and shales are commonly calcareous, whereas the claystones show little or no reaction to acid.

Vertical orange streaks are common in the clay beds. These streaks can usually be traced up the outcrop to ironstone layers or limonite balls in the same bed or an overlying one. The ironstone layers in the clays are less than 6 inches thick, and having greater resistance to erosion, form benches as much as 2 feet wide. These ironstone layers and the benches they form are sometimes good markers to carry correlations for short distances.

Previous reports (Fisher, 1953, and Benson, 1952) have referred to bentonitic clays in the Tongue River Formation. Bentonitic clays present in the Williams County area are indicated in Plate 3 by a "B." The bentonitic clay at one location, measured section 17 (pl. 3), swells when placed in water.

Gypsum (selenite) is concentrated on the surface of many clay and shale outcrops. The clays, claystones, and shales contain abundant plant fossils and many gastropods and pelecypods. The plant fossils are usually leaf imprints, twig or branch imprints, and petrified stumps (fig. 8).

Jointing in the clay beds is common and normally vertical. Many of the joint faces have rust-colored stains or gypsum crystals or both.

Lignite

Lignite beds are found at almost every bedrock outcrop in Williams County. They range in thickness from about 1 inch to over 10 feet. The lignite beds are the most persistent beds in this area, and they can often be traced for many miles, whereas the overlying and underlying beds may grade from one lithology to another. Even so, some of the lignite beds do pinch out in short distances.

Lignite, and its weathered equivalent leonardite, range from dark reddish brown (10R 3/4),to brownish black (5YR 2/1),or black (N1). Commonly associated with the lignites are brightly multicolored accessory minerals. The lignite ranges from almost entirely organic material to laminated clays or shales and organic material. On weathered surfaces lignite beds are commonly soft and broken, both along bedding planes and vertically. Unweathered lignite is hard, brittle, and uniform.

Fossil wood is characteristic of the lignite. Some of it still retains its woody texture, but others are carbonized or silicified.

"Scoria" or baked sediments

"Scoria", a term applied in North Dakota to volcanic-like rocks that formed when a lignite bed burned, baking the surrounding sediments into a scoria-like rock. This "scoria" can be greater than 60 feet thick or as little as 10 feet thick. In Williams County, the "scoria" is restricted to narrow bands about 150 feet wide that follow the margin of the outcrop. It is common along the Missouri River between Williston and the Mountrail-Williams County line and in some isolated outcrops at Bull Butte, T. 156 N., R. 104 W., and in the Scoria Creek valley near Hanks.

"Scoria" is generally light red (5R 6/6) or moderate pink (5R 7/4); but some is dark reddish brown (10R 3/4).

The original lithologies of the "scoria" were silt, clay, shale, and sand. Columnar jointing is sometimes found in "scoria" derived from

FIGURE 8. **Petrified stump from the Sentinel Butte Formation, NE 1/4 NE 1/4, sec. 20, T. 153 N., R. 99 W.**

FIGURE 9. **Columnar jointing in a sandstone "scoria," NE 1/4 NE 1/4, sec. 16, T. 153 N., R. 100 W.**

sand. Individual joint columns are generally about 1 to 2 inches in diameter and less than 1 foot long (fig. 9), much smaller than columnar jointing in volcanic rocks.

QUATERNARY

Preglacial Deposits

WIOTA GRAVEL

The Wiota Gravel was named by Jensen (1952) for gravels and associated sediments near Nashua, Montana, that were deposited by streams and rivers prior to local glaciation. They were deposited below the Flaxville plain and are eroded primarily from Flaxville and higher gravels.

Howard (1960) described and named two gravel units in eastern Montana and western North Dakota that are lithologically similar to the Wiota Gravel except that they were deposited by the Yellowstone River, whereas the type Wiota Gravel was deposited by the Missouri River. They are the Cartwright Gravel and Crane Creek Gravel, which are lithologically identical, but are found on different bench levels along the Yellowstone and Missouri Rivers.

The type Wiota Gravel and the Williams County brown quartzitic gravel were examined in the field and determined to be similar. In this report, the Cartwright and Crane Creek Gravels mapped by Howard (1960, pl. 1) and additional exposures mapped during the present study in Williams County are called Wiota Gravel.

The Wiota Gravel in Williams County occurs at two, possibly three, levels on benches along the valley wall of the prediversion course of the Yellowstone River. The three bench levels at which Wiota Gravel are found are about 2,030, 2,085, and 2,145 feet above sea level (fig. 10). Howard (1960) reported an exposure at Hoffland Flats (pl. 1), but this has since been covered by the rising water of Lake Sakakawea.

Stratigraphic position, thickness, and age

The Wiota Gravel rests on Paleocene rocks of the Tongue River and Sentinel Butte Formations. Overlying the gravel is glacial till. The gravel ranges in thickness from 6 to 18 feet and is generally about 10 feet thick.

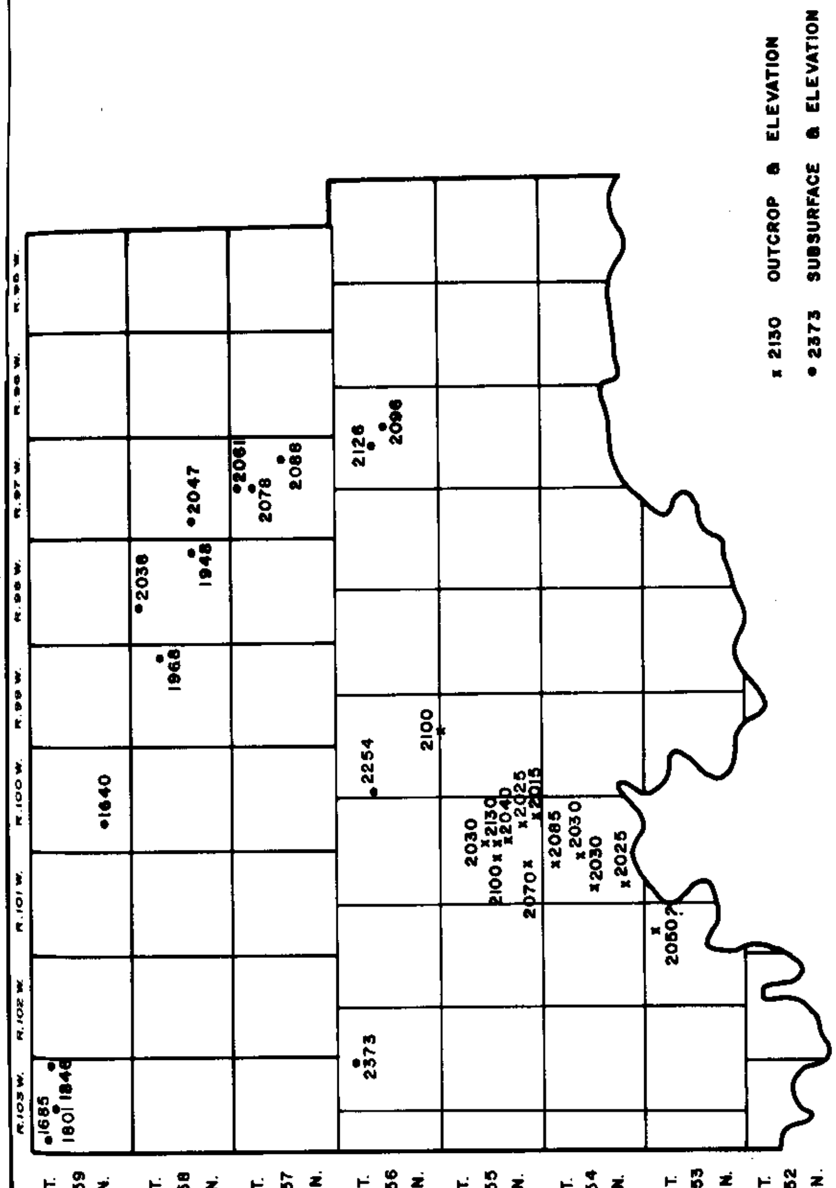

FIGURE 10. Localities and elevations of brown quartzitic gravels.

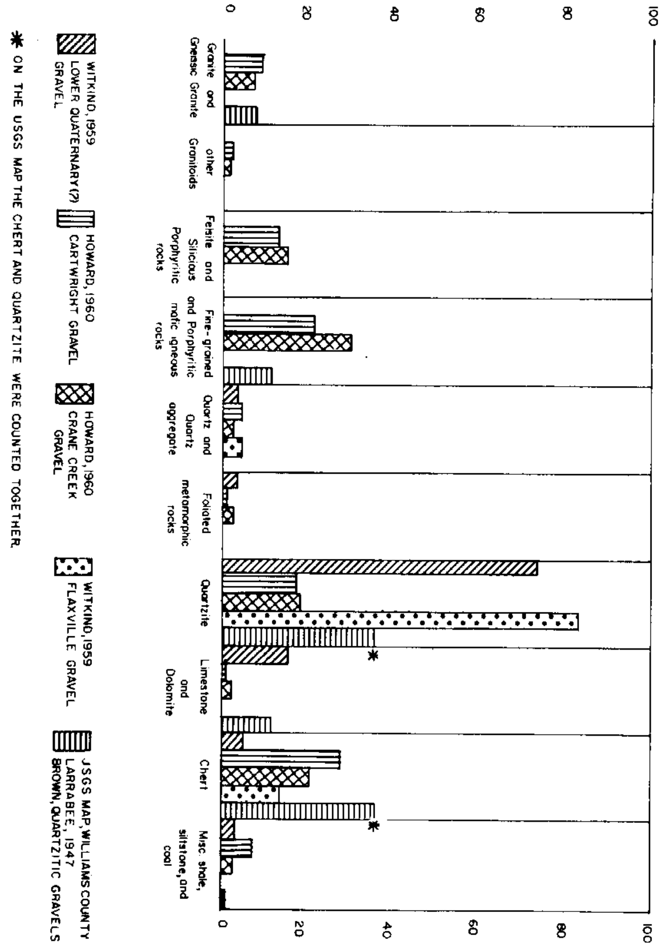

FIGURE 11. Pebble counts of brown quartzitic gravels in Williams County and surrounding area.

No fossils were found in the Wiota Gravel in Williams County, but fossils identified as probably Pleistocene in age were found in the type area by Jensen (1964).

Because no glacial deposits were found beneath the Wiota Gravel and the benches on which the gravel rests are on the valley wall of the prediversion Yellowstone River, the gravels must be preglacial or prediversion in Williams County.

Lithology

The Wiota Gravel in Williams County is similar to the Flaxville Gravel and other gravels of Quaternary age described by Colton (1955). They are well rounded, water-worn pebbles usually 2 inches or less in diameter. Most of the deposits in Williams County appear to have less sand and silt than those described by Jensen (1964). Chert and quartzite comprise about 70 to 80 per cent of the deposits (Larrabee, 1947). Rhyolite ranges from 2 to 10 per cent and averages 7 per cent; limestone and dolomite range from 0 to 12 per cent and average 5 per cent (fig. 11).

Gravel deposits in several places in Williams County are composed of brown quartzitic gravel as well as abundant glacial erratics. These deposits are not Wiota Gravel because Jensen (1964) said that the Wiota Gravel should be restricted to deposits that are mostly nonglacial in origin.

Glacial Deposits

Glacial drift is the most extensive surface deposit in Williams County. Except for the area along the Missouri River (pl. 1) and a few isolated bedrock outcrops, the surface is underlain by glacial drift (fig. 12). Glacial deposits are of three basic types: till, sand and gravel, and clay and silt.

TILL

Distribution and thickness

Glacial till is a heterogeneous mixture of all particle sizes from clay through boulders. Till is widely distributed throughout the county

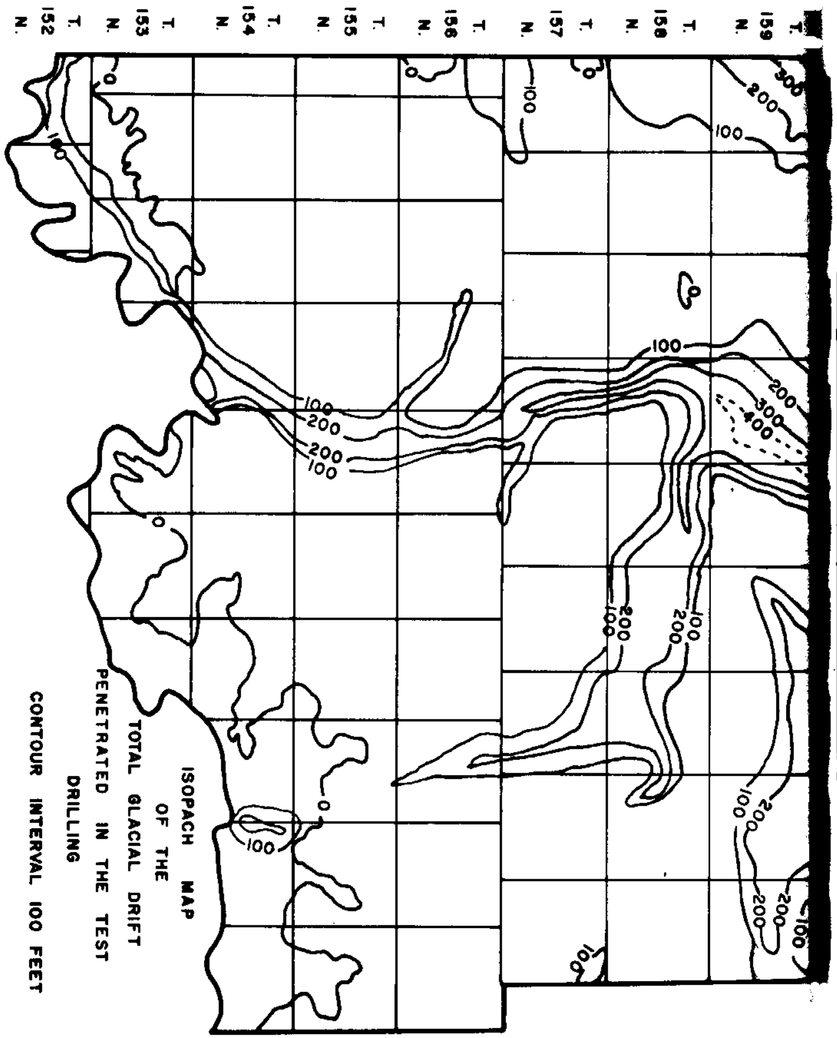

FIGURE 12. Isopach map of glacial drift in Williams County.

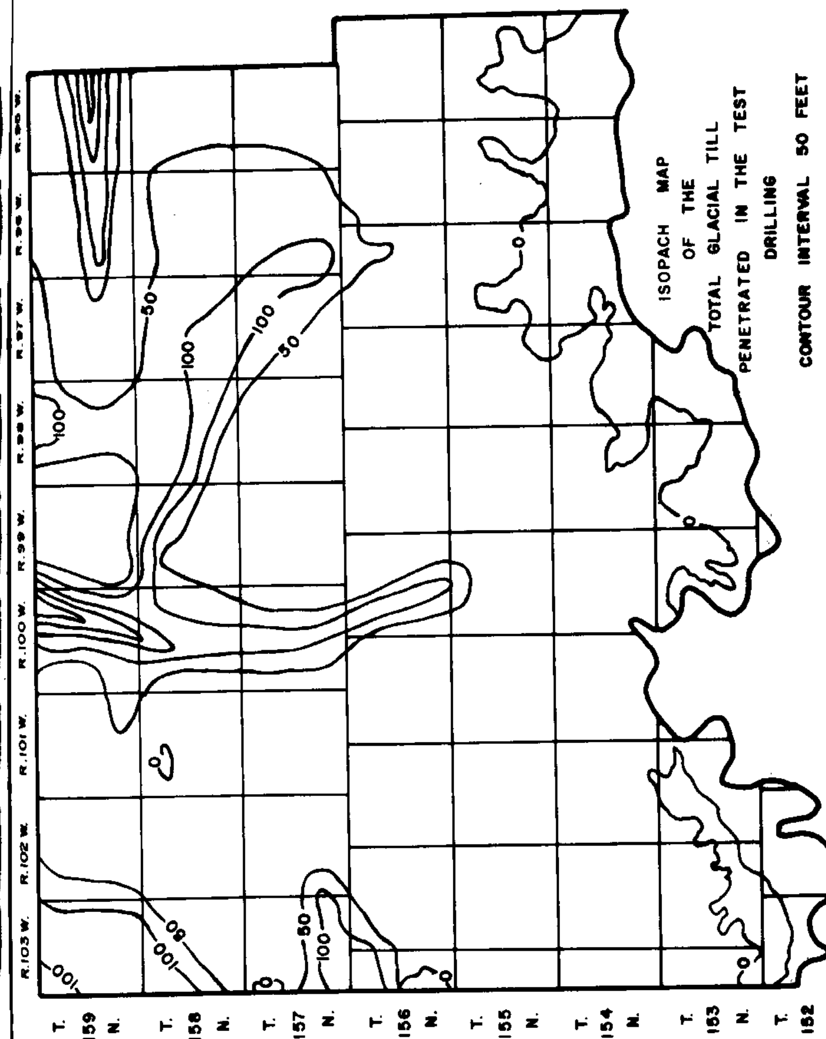

FIGURE 13. Isopach map of glacial till in Williams County.

and is absent only where post-glacial erosion has removed it as in the badlands (topographic Unit A, figure 2) along the Missouri River where several dozen square miles are underlain by bedrock, alluvium, or colluvium.

The thickness of the till ranges from only a few inches near the Missouri River to over 250 feet in T. 159 N., R. 100 W., in northern Williams County. There is a close association between the till thickness and the bedrock topography. Figure 13, a till thickness map, (compare with Plate 2, the bedrock topography map) shows the till is generally thickest in the bedrock valleys such as the Ray channel or the valley of the pre-glacial Yellowstone River. Aside from those areas where the till has been eroded, the thinnest deposits of till are on the bedrock highs by the uplands (topographic Unit C). One exception to this generality is north of Bull Butte where the till is over 100 feet thick and on a bedrock high.

Lithology

Till in Williams County can be described as uniformly variable. That is, variability of the lithology of the till exists at any given location; but the variability is usually within predictable limits. For example, one road cut may expose a sandy-clay till, a stony-loam till, and a silty-clay till, whereas another road cut 15 miles away might expose a sandy-loam till and a sandy-clay till. The till is generally a mixture of nearly equal parts of clay, silt, and sand with a few per cent of gravel.

The color of the till changes both vertically and horizontally. In the northern tier of townships the upper 4 or 5 feet is generally light olive gray (5Y 5/2) when moist. The dry till is lighter hued; usually yellowish gray (5Y 7/2) or light olive gray (5Y 6/2). Till south of the northernmost tier of townships has more red in it. The color in the upper few feet ranges from yellowish gray (5Y 7/2) to dark yellowish brown (10YR 6/6) when moist and lighter when dry. Throughout the area the upper 1 or 2 feet of drift has light gray to white overtones due to the presence of much calcium carbonate in the form of caliche.

Till cuttings from test holes are generally moderate yellowish brown (10YR 5/4), dark yellowish orange (10YR 6/6), yellowish gray (5Y 7/2) or light brown (5YR 5/6) in the upper 35 to 45 feet, the oxidized zone. Below these depths in the unoxidized zone, the till is much darker, normally olive gray (5Y 4/1), but sometimes medium gray (N5) or dark greenish gray (5GY 3/1). At four locations, the lighter, more reddish colors, were found below the olive gray zone as well as in the upper zone.

Two main groups of rock types constitute the gravel size fraction of the till: those of local origin and those of distant origin. The local types are all from the Fort Union Group or from Tertiary or Quaternary gravels. Fort Union rock types are shale sandstone, lignite, "scoria," petrified wood, ironstone, and some limestone. Quaternary gravels are either Wiota or Flaxville Gravel which are primarily chert, quartzite, and agate. The distant rock types are of Mesozoic, Paleozoic, or Precambrian origin. They are primarily granitic, metamorphic, carbonate, and shale.

Most of the larger particles in the till, pebbles to boulders, are angular to subangular. Throughout the area are occurrences of gravel derived from the Wiota and Flaxville Formations in the till. Most of them are blade shaped and are rounded to well rounded. Occasional rounded glacial pebbles from the Canadian Shield also occur. The sand-size grains in the till are mostly angular to subrounded. Silt particles are generally subangular and are blade shaped. Most angular grains are of local origin; they are primarily shale, "scoria," petrified wood, and lignite fragments from the Fort Union Group.

Most of the till is firm, but easily crushed with moderate pressure in the hand. Extremely hard tills, as are found in eastern North Dakota (Bluemle, 1967) are absent. Hardness of the till in the upper few feet is variable due to secondary enrichment of the B-horizon.

Figure 14 is a graphic, descriptive, and electrical log of the materials penetrated in test hole 3233, in central Williams County. This data was selected as an example of the types of lithologies penetrated during test drilling. Descriptive and electrical logs were made for every test hole during this study. Descriptive logs for all test holes are published in Part II of the Williams County study (Armstrong, 1967).

SAND AND GRAVEL

On Plate 1, the glacial sand and gravel is in yellow. The most extensive surface deposit of sand and gravel is in the Little Muddy valley which extends from Williston to the Divide County line. Other large surface deposits are in Beaver Creek, southeast of Ray; west of Grenora, and in the valley at McGregor. In the subsurface, the sand and gravel is almost as extensive as at the surface.

Figure 15, a sand and gravel total thickness map, reveals the greatest thickness of sand and gravel in the bedrock valleys of the Ray channel and old course of the Yellowstone River (pl. 2). The upland areas (topographic Unit C) are almost devoid of thick sands and gravels.

Descriptive Log	
Logged by Larry Froelich, North Dakota State Water Commission	
Depth (Feet)	**Description**
0-4	Clay, sandy, yellowish gray, soft, fairly loose.
4-16	Clay, sandy with pebbles, dusky yellow, soft, slightly cohesive. (Till)
16-86	Clay, silty and sandy with pebbles, moderately soft, cohesive, tough, occasional rocks. (Till)
86-94	Sand, medium gray, moderately well sorted, subrounded, lignitic.
94-99	Clay, silty, olive gray cohesive, tight.
99-105	Sand, fine to coarse, gray, moderately well sorted, subangular and subrounded. Mostly quartz, lignitic.
105-140	Clay, silty and sandy with pebbles, olive gray, moderately soft to slightly hard, cohesive, very tight. (Till)
140-153	Sand, medium gray, very well sorted, subrounded, clean.
153-189	Sand, coarse and very coarse, gravelly, brown, moderately sorted, subangular and subrounded, mostly quartz and chert, drills good, rough in spots, taking some water.
189-203	Clay, silty, light gray, light greenish gray, greenish gray and brownish black, soft to slightly hard, interbedded, slightly cohesive to very tight, calcareous, highly carbonaceous in spots.

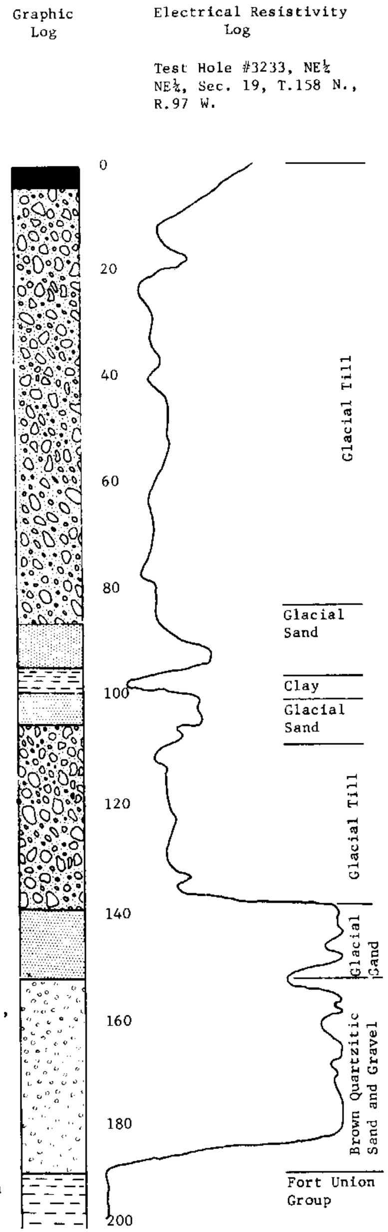

FIGURE 14. **Geologic, graphic, and electrical resistivity log of test hole number 3233, Williams County.**

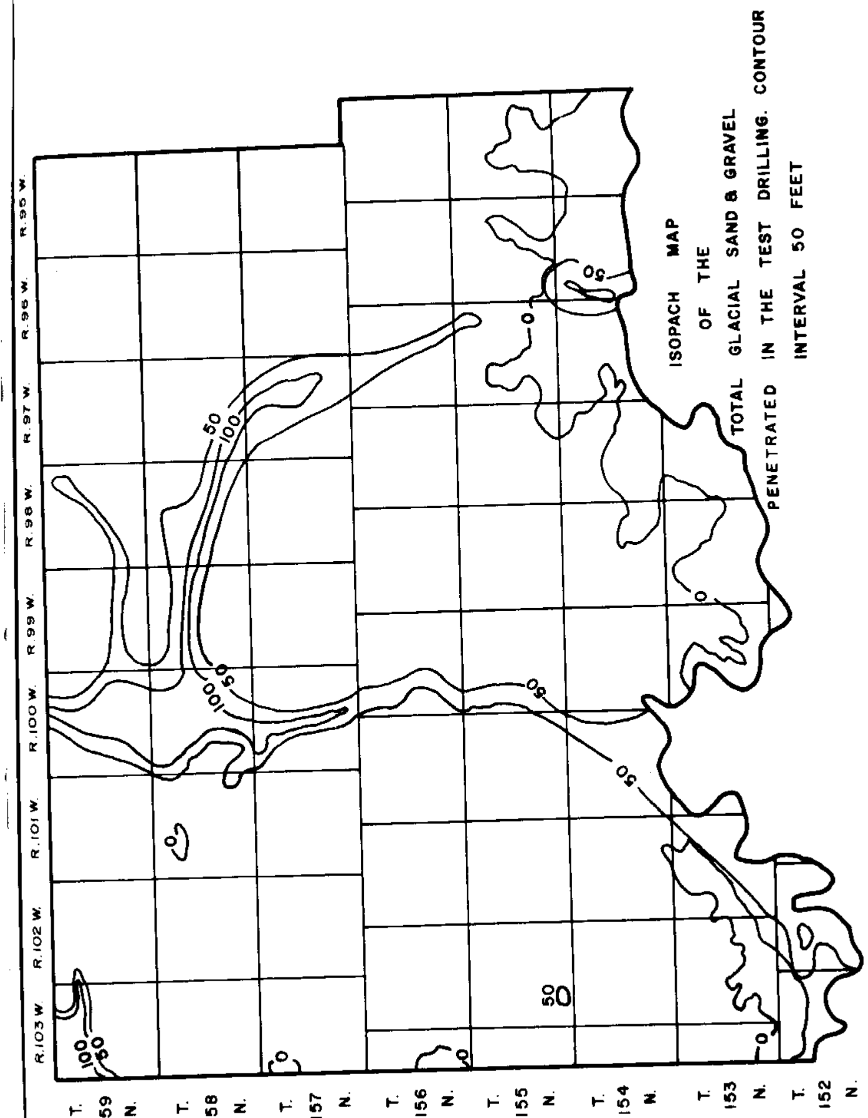

FIGURE 15. **Isopach map of the glacial sand and gravel in Williams County.**

Lithology

Sand and gravel in the upper 10 feet of most deposits are light olive gray (5Y 4/3) to yellowish gray (5Y 7/2). In several gravel pits near the base of the exposure at a depth of 10 to 12 feet, the sediments are stained black (N2), and just above this they are moderate reddish brown (10R 4/6). Subsurface sand and gravel have similar colors.

Individual gravel grains are subangular to subrounded and occasionally rounded. Sand grains are angular to subangular. The bulk of these deposits consist of granitics and carbonates. Field estimates and several pebble counts averaged 55 per cent carbonates, 20 per cent granitic, 5 per cent metamorphic, and 20 per cent local (sandstone, shale, and miscellaneous) rock types.

In the upper 3 to 4 feet of most sand and gravel deposits, individual grains have deposits of caliche on the underside. The caliche is as much as 3/8 of an inch thick. Many of the sand deposits have concentrations of black organic material, probably lignite that has concentrated during deposition. Iron oxide stains are also quite common.

One sand and gravel deposit, NE 1/4 NW 1/4 sec. 7, T. 157 N., R. 101 W. contains balls of glacial till mixed in with the gravel.

The linear sand and gravel deposit along Cottonwood Creek, map symbol Kt, is a fairly well-sorted deposit. The deposit extends from the top of the Cottonwood Creek valley wall to the valley floor. In some places are large concentrations of cobbles and boulders.

The sand and gravel deposits indicated by the symbol Drg on Plate 1 are linear, steep-sided ridges segmented and sinuous. They range from well sorted to poorly sorted. West of Grenora are several well-sorted deposits of this type. The one extending from the SE 1/4 NE 1/4 sec. 16, T. 159 N., R. 103 W. to Horseshoe Lake is very large, up to 50 feet high, with well-sorted sand and gravel deposits. Another well-sorted sand and gravel deposit crosses U. S. Highway 85 about 2 miles south of the Divide County line. An example of a poorly sorted deposit occurs 3 miles west of the junction of U. S. Highway 2 and North Dakota Highway 40. Many smaller deposits that are found throughout the county are variable in their sorting.

Another type of sand and gravel deposit that is generally well sorted is indicated by K on Plate 1. This type of deposit is generally a knob, hill or mound, well sorted and stratified, and variable in size. Similar to these deposits are the deposits indicated by IU on Plate 1 which are usually not as well sorted and do not have any definite shape.

The largest, most extensive, and best-sorted deposits are the areas of yellow on Plate 1. Those with the symbol Op are gently rolling areas that are composed of large amounts of sand and gravel. Sorting varies throughout the deposit; for example, one part may be primarily beds of sand with a little gravel, and another part may be gravel with some sand. The yellow areas with the symbol Oc are similar to those with the symbol Op but are hilly with as much as 50 feet of local relief. Generally, the best sorted of all the deposits in Williams County are those with the symbol Ot on Plate 1, especially the deposits near McGregor. Subsurface sands and gravels penetrated in the test drilling have sorting similar to the surface sands and gravels.

SILT AND CLAY

Silt and clay deposits of glacial and proglacial origin are extensive in eastern Williams County. The areas of light blue on Plate 1 and designated either Lp or Lc are the glacial silt and clay deposits. There are two types of silt and clay deposits; one is a nearly flat deposit designated by Lp, and the other is gently rolling and sometimes hummocky as designated by Lc on Plate 1. An example of a gently rolling deposit is the area called locally the ' Big Meadow" located 5 miles south of Hamlet. The nearly flat silt and clay deposit is typified by the area 3 miles west and 2 miles north of Ray. In addition to the silt and clay deposits in the eastern part of the county, three small areas of silt and clay deposits occur north of Bull Butte in T. 157 N., R. 103 W. All of the silt and clay deposits of glacial or proglacial origin are found associated with topographic Units E through H. The larger silt and clay units are represented by topographic Unit I in Figure 2.

The greatest known thickness of the silts and clays at the surface is 26 feet in a test hole 1 mile west and 6 miles south of Hamlet. Figure 16, a thickness map of the total silt and clay in the county, indicates that the thickest areas coincide with the old course of the Yellowstone River. Near Williston buried deposits exceed 200 feet in thickness.

Lithology

Generally the silt and clay deposits are well sorted into clayey silts and silty clays. Near the edge of many of the deposits are associated sands and gravels. These occur in the form of ridges and are sometimes continuous for 1 1/2 miles. The sediment generally grades from coarser

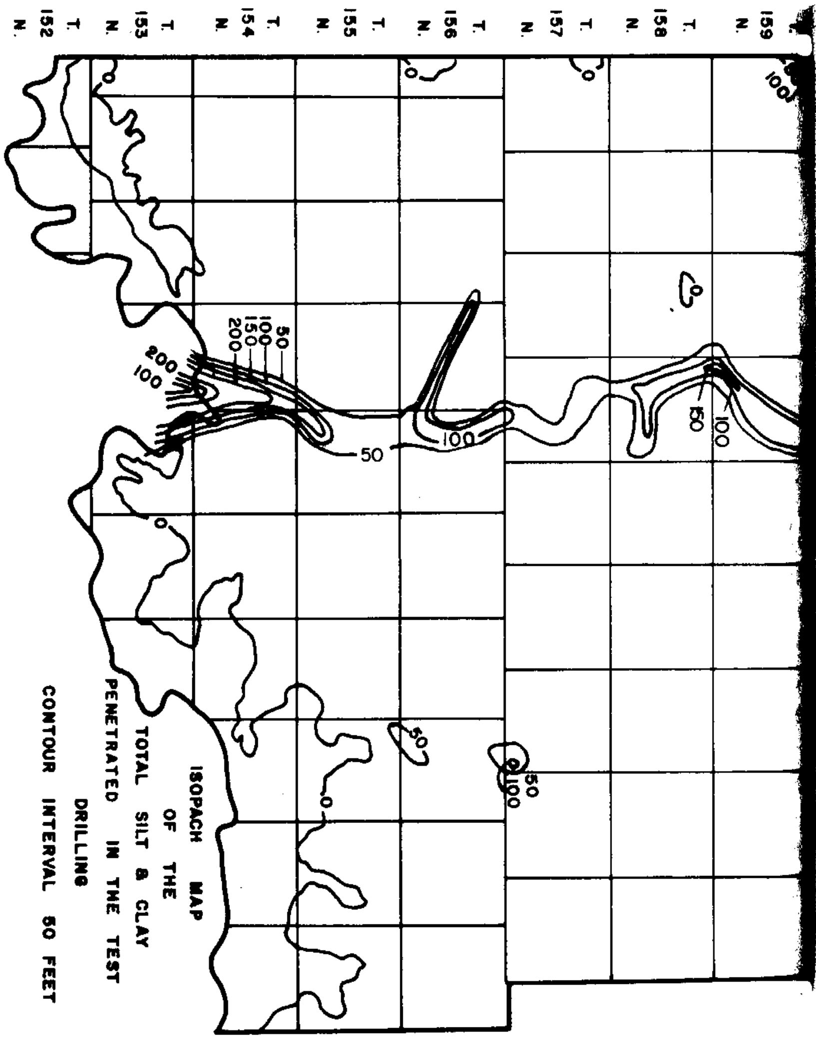

FIGURE 16. Isopach map of the glacial silt and clay in Williams County.

at the margin, especially when there is a sand or gravel rim, to fine clay at the center of the deposit. Colors of the deposits range from yellowish gray (5Y 7/2) to olive gray (5Y 4/1). In the upper few feet of the deposits are iron oxide stains and small, less than 1/4 inch long, gypsum crystals.

Bedding in the silts and clays are present, but exposures of the bedding are few and shallow so that sedimentary and structural characteristics are not easily seen. One good exposure is just north of the Divide-Williams County line along the edge of the Wildrose sewage lagoon. The alternating silt and clay beds in the exposure are about 1/8 to 1/4 inch thick.

Postglacial Deposits

ALLUVIUM

Alluvium occurs along the stream and river channels and in the sloughs of Williams County. The largest area of alluvium, along the Missouri River west of Williston, is indicated by the gray areas on Plate 1, with the symbols A or A_t. The second largest area of alluvium is in the Little Muddy valley from Williston north to Scoria Creek and west to Grenora. All of the streams tributary to the Little Muddy and Missouri River has alluvium usually only several hundred feet wide. The sloughs in the area of nonintegrated drainage contain postglacial to recent alluvium. The thickness of the alluvial deposits is variable and often difficult to distinguish from the glacial deposits. The alluvium along the Missouri River ranges from a few feet on some of the areas designated A_t on Plate 1 to 178 feet in sec. 8, T. 152 N., R. 103 W. on the floodplain. The small tributary valleys have narrow alluvial deposits 5 to 25 feet thick. Sloughs contain up to 20 feet of alluvium. Topography of the alluvium is generally nearly level as represented by topography Unit D, Figure 2.

Lithology

The alluvium is composed of clay, silt, sand, and gravel. The upper beds along the Missouri River and Little Muddy River are generally composed of finer material than the lower beds. Alluvium in the side valley is composed of clay, silt, and sand with a little gravel especially near the base of the beds. Bedding is distinct with separate beds of sand, silt, and clay most common. Dark silty and clayey beds are characteristic and contain large amounts of organic material. The beds along the Missouri and Little Muddy Rivers have an overall color of light gray (N7). Beds along the tributary valleys have a more yellowish hue and are commonly yellowish gray (5Y 7/2). Figure 17 is an alluvial deposit along the Missouri River. The upper unit is deposited on top of an old trash pit which contained an emblem of an Ajax 6 automobile which was manufactured no earlier than 1926. The 1 1/2 feet of alluvium cannot be any older than 39 years, giving some indication of the rate of alluvial deposition in this area.

FIGURE 17. A buried trash pit overlain by 1 1/2 feet of alluvium along the Missouri River in the NW 1/4, sec. 18, T. 153 N., R. 97 W., McKenzie County.

The surface alluvium is characteristically oxidized in Williams County, although at depth it is unoxidized. Most of the individual sand grains from the test holes in the Missouri River are subangular to rounded. Sand grains in alluvium along the tributary valleys are angular.

The alluvium along the Missouri River and its side valley is derived primarily from the Tongue River and Sentinel Butte Formations. It consists of clays, silts, sands, "scoria," coal, and petrified wood. Alluvium along the Little Muddy River and its tributaries is derived from glacial deposits and consists of clays, silts, sands, and gravels.

AEOLIAN DEPOSITS

Wind-blown sediments are present in Williams County and overlie every type of sediment. Generally, they are thin and scattered and were not mapped during this study. In T. 154 N., Rs. 96 and 97 W., there are sand dunes that are several feet thick and about 3 square miles in area. These deposits lie in a low area along the Missouri River and are probably from an alluvial source. Dunes are 1 to 4 feet high, and blowouts are common.

SLUMP BLOCKS

Along the Missouri River are large blocks of bedrock which have slumped from 10 to 100 feet. This slumping usually occurs where oversteepening has taken place, such as along the outside of a meander loop where the river impinges against the bedrock.

QUATERNARY HISTORY

In North Dakota a definite stratigraphic break between Tertiary and Quaternary has not been recognized. The earliest Quaternary deposition in northwestern North Dakota and northeastern Montana is the Wiota Gravel. The next oldest known deposit is the Flaxville Gravel which is identified as possibly Miocene or Pliocene by Collier and Thom (1917). However, Alden (1932) and Bluemle, (1962, Erosional surfaces and glacial geology along the southwest flank of the Crazy Mountains, Montana, Montana State College, unpublished master's thesis) suggest that some of the Flaxville Gravel may have been deposited during early Pleistocene time.

In Divide County are several remnants of gravels at elevations of more than 2,300 feet which are lithologically similar to the Flaxvill Gravel (Hansen, 1967). These gravels are disturbed, dipping as much as 80° to the west, and are probably at lower elevations than whe deposited by the rivers. The Flaxville Gravel near Flaxville, Montana, i at an elevation of about 2,700 to 2,800 feet. In Williams County, jus north of Bull Butte in sec. 1, T. 156 N., R. 104 W., test well numbe 3284 penetrated a gravel at an elevation of 2,373 feet (fig. 12). Th Flaxville Gravel east of the Missouri-Yellowstone divide is at a elevation of more than 2,700 feet. Projecting the gradient of th Yellowstone River during the time of Flaxville deposition as calculate by Alden (1932, p. 30) (4 feet in a mile), the expected elevation of th Flaxville at Bull Butte would be about 2,470 feet. Bull Butte an surrounding areas are over 2,500 feet in elevation, and Fort Unio Formation beds crop out at the top of Bull Butte (more than 2,50 feet). It seems likely that the gravels penetrated in test hole numb 3284 are displaced Flaxville Gravel.

At the close of deposition of the Flaxville Gravel, the Missouri Yellowstone, and Little Missouri Rivers began to incise themselve below the Flaxville level. Rejuvenation was probably initiated in th Late Tertiary or Early Quaternary. The downcutting continue uninterrupted into Pleistocene time, resulting in a topography similar t that represented in Figure 18.

During Early Quaternary time, gravels of western an southwestern origin were deposited on terraces along the Yellowston Missouri, and Little Missouri Rivers (fig. 18). These gravels are probabl reworked Flaxville and older gravels. Figure 10 shows the locations an elevations of brown quartzitic gravels exposed or penetrated by te drilling in Williams County. Except for the one deposit of gravel at a elevation of 2,373 feet, all of the deposits of gravel in Figure 10 a within two ranges of elevation: one between 1,950 and 2,250 feet, an one between 1,640 and 1,848 feet. The gravel at 1,950 to 2,250 feet probably equivalent to Alden's number 2 bench and Howard's (196 Cartwright Gravel. These deposits of gravel are equivalent lithological to the Wiota Gravel described by Jensen (1964) near Nashua, Montan The Wiota Gravel in Williams County is the alluvial deposits of t Missouri, Yellowstone, and Little Missouri Rivers prior to glaciation the area.

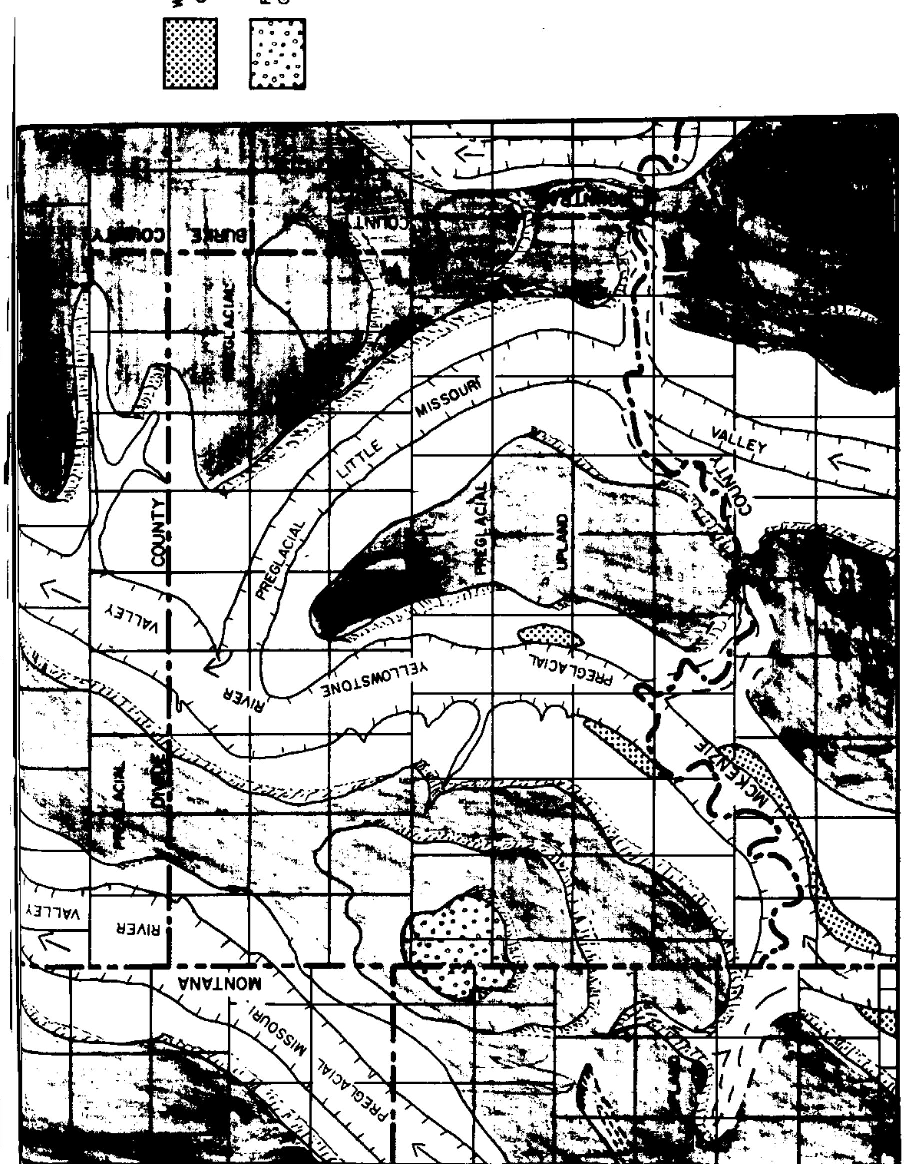

FIGURE 18. Preglacial drainage and topography in Williams County.

The lower gravel (1,690 to 1,850 feet), about which little is known, occurs in the preglacial valleys of the Missouri and Yellowston Rivers, but none has been found in the preglacial Little Missouri Rive valley in Williams County. This gravel could possibly represent preglacial erosion period in the early or middle Pleistocene. Onl fragmentary evidence has been found for pre-Wisconsinan glaciation i North Dakota (Clayton, 1966) which may indicate that one or more o the three pre-Wisconsinan glaciers did not extend to western Nort Dakota. These gravels may be equivalent (based entirely on elevations to the Crane Creek Gravel of Howard (1960).

It is not known when glacial ice first advanced into North Dakota Some of the radiocarbon dates are greater than 35,000 years, but mos dates are around 10,000 to 12,000 years B. P. Some evidence fo pre-Wisconsinan drifts are red colored highly weathered gravels i Logan County (Clayton, 1962) and in Mountrail County (Clayto personal communication); jointed, hard tills overlain by oxidized zone boulder pavements and other tills in northeastern North Dako (Bluemle, 1967). In Williams County, the drift is all lithologicall indistinguishable and no till or gravel was found that could be calle pre-Wisconsinan. To the south, in McKenzie County, are thin an scattered till deposits that may be of pre-Wisconsinan age.

The Sperati Phase

As the first glacial ice advanced from the north or northeast int North Dakota, the northward flowing streams and rivers were damme causing large proglacial lakes. The lakes rose higher, as the ice margi advanced and eventually spilled over cutting channels across the divide in a southeasterly direction. This channel cutting probably took plac initially on the northeastern side of the Missouri Coteau Escarpme (fig. 1), as suggested by Laird (1967). Lobate tongues of ice extende far out in front of the main ice mass as the ice advanced up the majo valleys cutting across the Missouri Coteau.

The ice first entered Williams County by way of the Yellowston valley. As the glacier moved across the county, the Missou Yellowstone, and Little Missouri Rivers were dammed to form larg lakes (fig. 19). Silt and clay deposits accumulated in these valleys (pl. 4

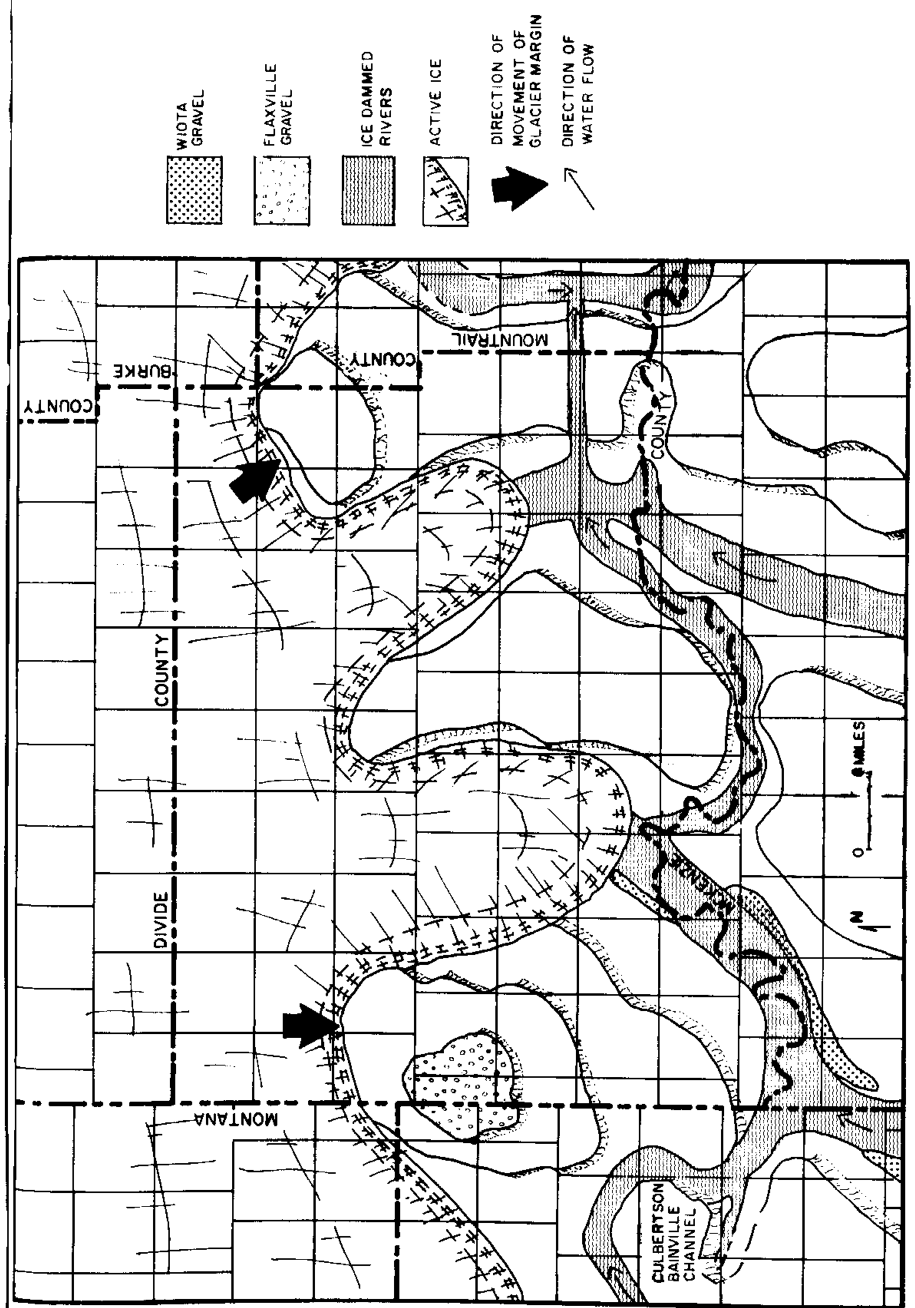

FIGURE 19. The Sperati Point phase including initial diversion of the Missouri, Yellowstone, and Little Missouri Rivers on the Missouri Plateau.

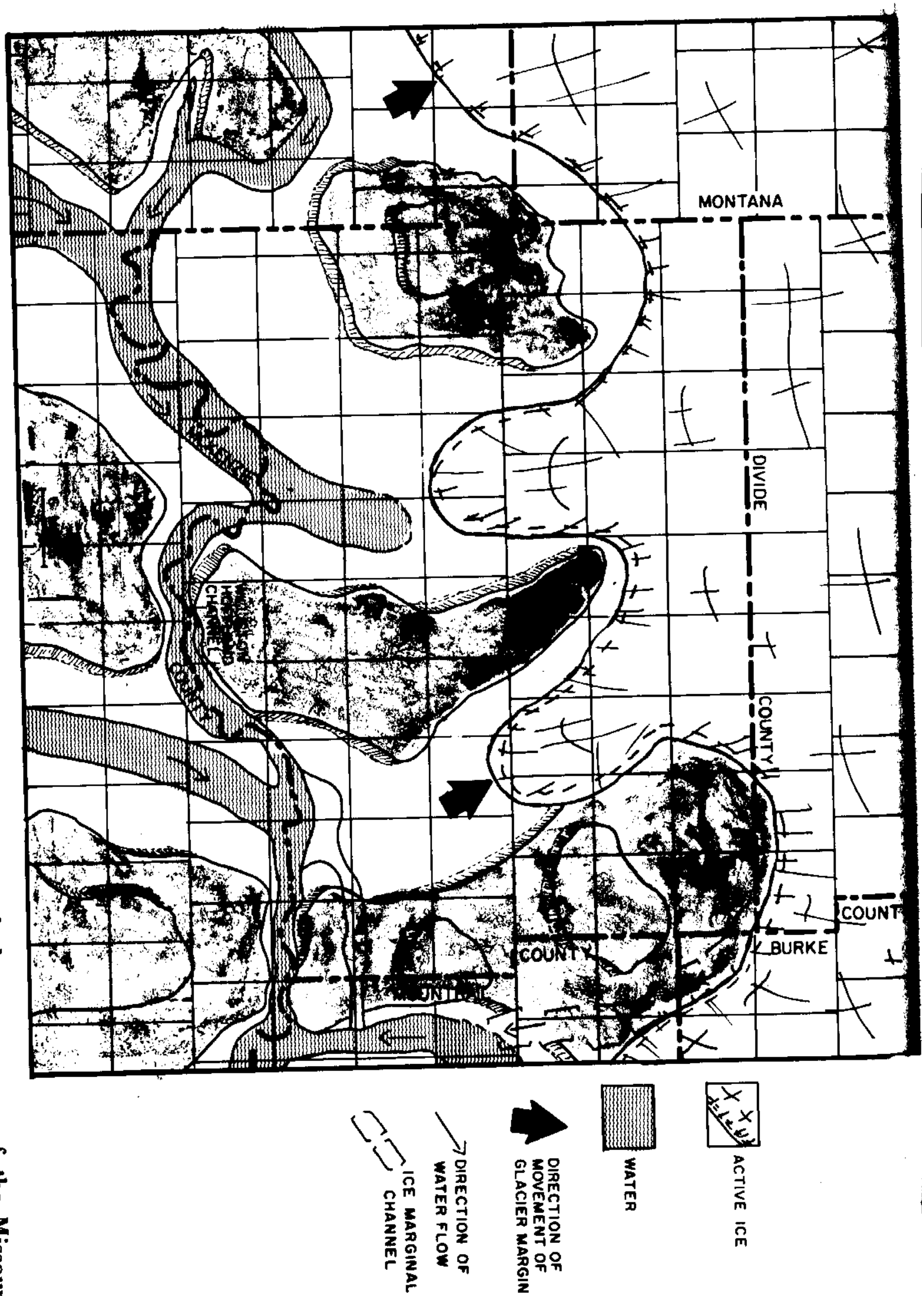

FIGURE 20. Recession of the Sperati Point phase ice and establishment of the new course of the Missouri and Yellowstone Rivers.

section A-A'). The water impounded in the Missouri valley probably spilled across the divide into the Yellowstone valley during the initial advance by way of the Culbertson-Bainville channel, in eastern Montana. A diversion channel was cut between the Yellowstone valley and the Little Missouri valley (fig. 20). Another channel was cut between the Little Missouri valley and an unnamed valley in the position of the present White Earth valley in western Mountrail County. Soon after these diversion channels were cut, the ice advanced across them, again damming the rivers of the area. During the initial advance of the ice, there was considerable erosion of buttes and valleys. Probably some ice marginal meltwater channels on the divides were cut at this time and are now buried (pl. 1).

This initial advance of ice probably extended to the glacial limit near Sperati Point in central McKenzie County. It deposited the Morton drift, and due to its lack of deep weathering in areas of little erosion is thought to possibly be early Wisconsinan by Clayton (1966).

As the initial advance of ice wasted and the ice margin withdrew to the north, the major drainageways were grossly altered from the preglacial. The Missouri and Yellowstone Rivers now joined in western North Dakota and flowed eastward across the southern boundary of Williams County. The Little Missouri River joined the Missouri River in eastern Williams County (fig. 20). The ice withdrew to the north, an unknown distance. If the initial advance was pre-Wisconsinan, then the ice probably withdrew entirely out of North Dakota. The glacier was probably lobate, because when it advanced it had proglacial lakes in front of the lobes in the valleys as evidenced by the silt deposits on top of the till deposits in test hole number 3085, sec. A-A', Plate 4. The topography was changed considerably as the highs were rounded and eroded and the lows were filled with drift and lake sediments.

The Charlson Phase

Ice again advanced into Williams County and beyond during the late middle or late Wisconsinan. This ice advanced almost as far as the initial advance in central McKenzie County. Along the eastern edge of the ice in McKenzie County (fig. 21) on high ground, a band of dead-ice moraine 18 miles long was deposited, the Charlson dead-ice end

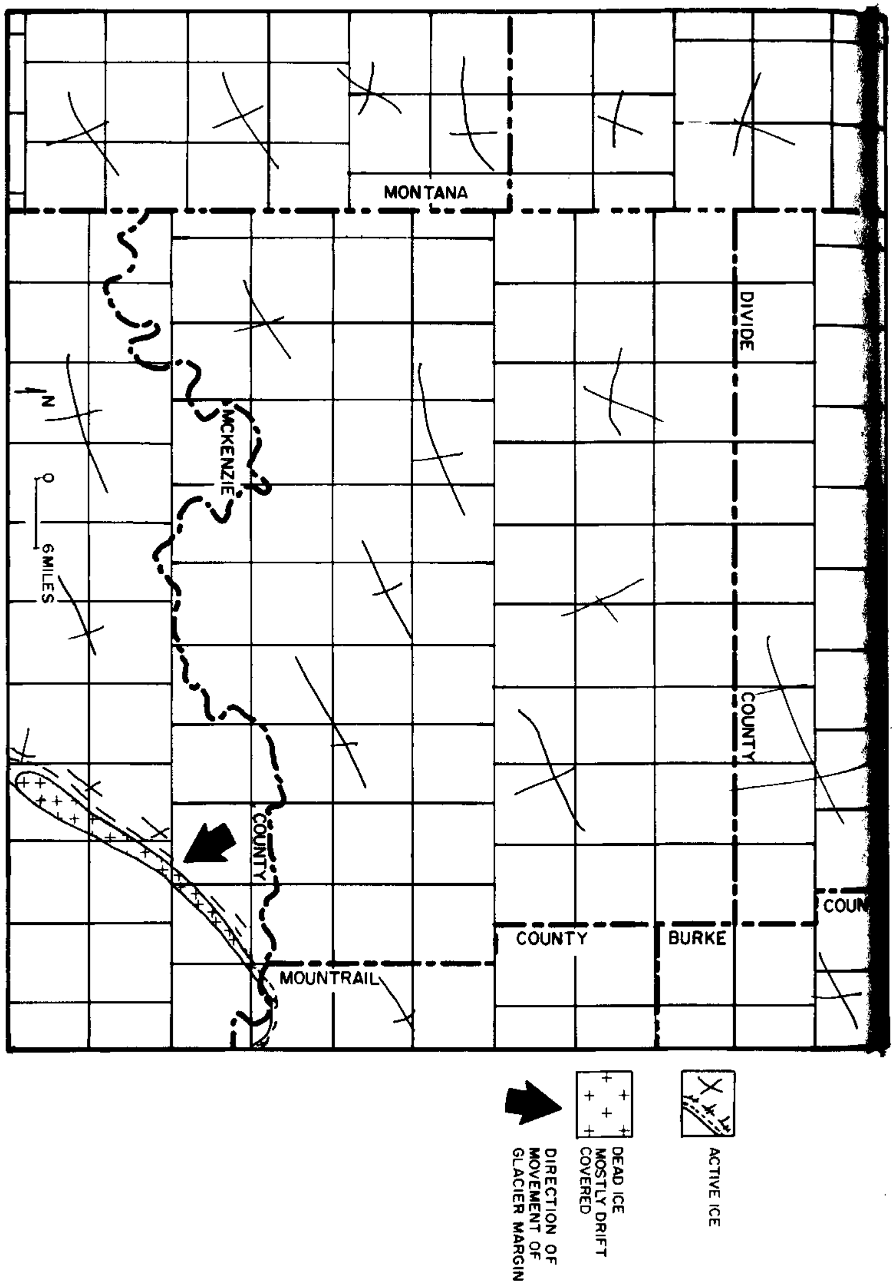

FIGURE 21. Second advance of ice diverting the Little Missouri River to its present course and deposition of the Charlson dead-ice moraine.

moraine. It has many fresh dead-ice features with nonintegrated drainage similar to those described by Clayton (1967). On the basis of similarity of topography, Clayton (1966) has very tentatively correlated the Charlson moraine with the Zeeland moraine in McIntosh and Emmons Counties. No radiocarbon dates have been made from the Zeeland-Charlson drift. The dead-ice features of the Charlson moraine are almost as fresh as the dead-ice features on the Missouri Coteau which have been dated from 9,000 to 12,000 years before present. If there is any validity in age relationships based on similarity of topography for western North Dakota, then the Charlson moraine is probably of Late Wisconsinan age. In other parts of the state, especially Burleigh, Emmons, Logan, and McIntosh Counties, the Burnstad drift is between the Morton and Zeeland drifts. There is no evidence in Williams County for the Burnstad drift, but it may be present in the subsurface.

As the Charlson ice reached its maximum advance, the Little Missouri River was diverted to its present course, to the east joining the Missouri River about 55 miles southeast of the pre-Charlson junction of the Missouri-Little Missouri River. At the time of maximum advance, the Yellowstone and Missouri Rivers were again diverted out of their channels and across divides. When the Charlson ice began to wane and the margin receded to the north, much of the present day topography of southern Williams County was formed.

Till deposits are present in the trench of the Missouri River in Williams County indicating glaciation after the trench had been cut. The most conspicuous deposit is the till in T. 154 N., R. 96 W. (pl. 1). Considerable erosion has removed most of the drift immediately adjacent to the Missouri River leaving badlands today. The Charlson ice probably withdrew entirely out of Williams County. During the withdrawal, it left large areas of low-relief, dead-ice moraine especially on the topographic highs (fig. 22). The dead-ice moraine is composed of many features, ice-walled lake plains and collapsed lake sediments both underlain by silt and clay, as shown on Plate 1 as Lc. The origin of this type lake is discussed by Clayton and Cherry (1967). Disintegration ridges of till and sand and gravel are a common feature of dead-ice moraine, and their origin is discussed in detail by Clayton (1967).

Ice-marginal channels were cut during recession of the ice margin. Stony Creek has a large amount of outwash sand and gravel terraces; Beaver Creek and Sand Creek are underlain by outwash sand and gravel. Cow Creek contains scattered terraces with remnants of glacial gravels

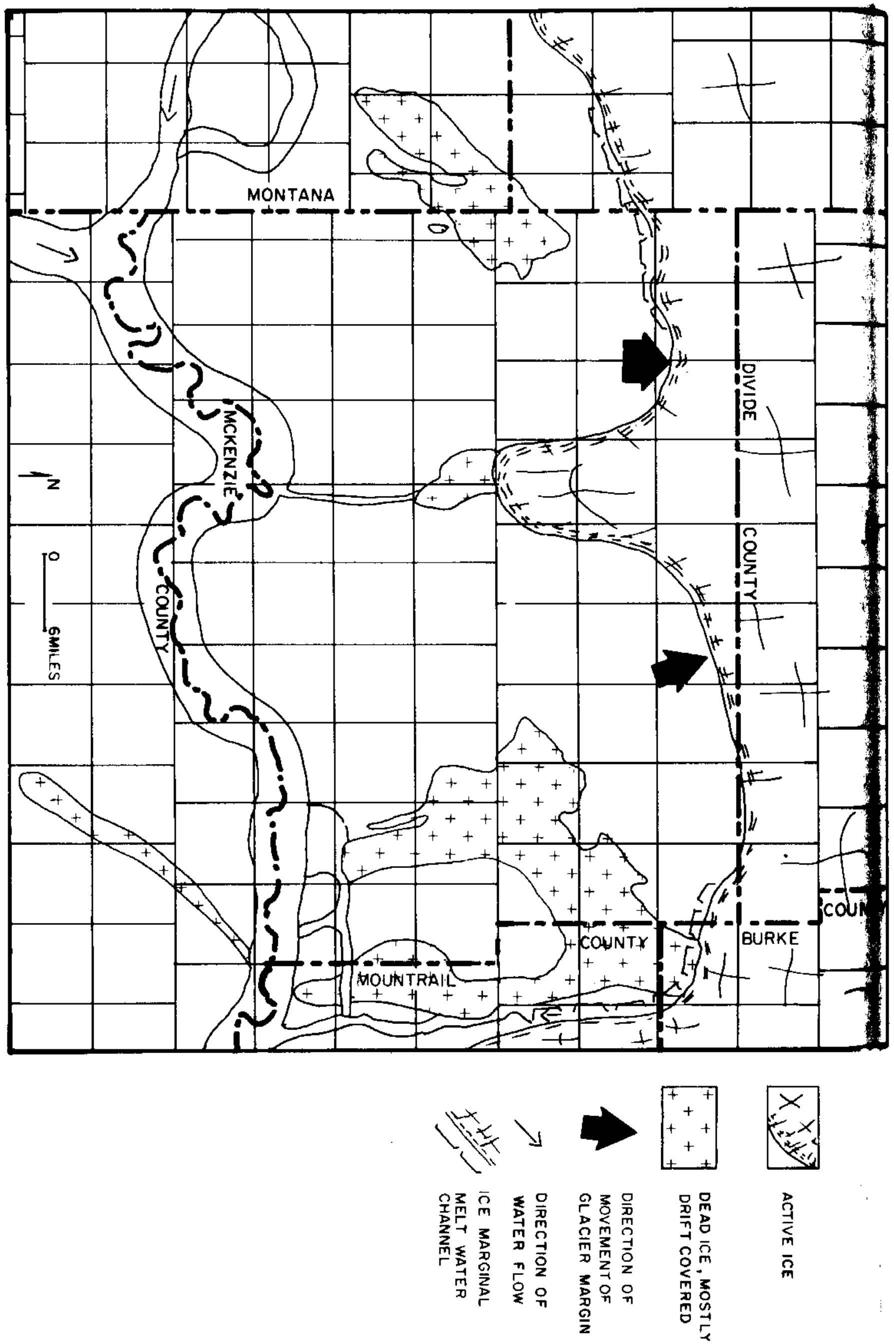

FIGURE 22. Recession of the Charlson phase ice.

on some. Many scattered sand and gravel deposits in the area of sheet moraine are small outwash bodies or ice-contact sand and gravel deposits.

It is possible, as suggested by Howard (1960), that Cow Creek terraces represent a temporary halt in the recession of the ice. This study suggests that the Charlson ice margin stopped receding temporarily to form the terraces while Howard said it was Middle Wisconsinan (?) ice. Some evidence that supports a temporary halt is; dead-ice moraine extends south as far as the mouth of Cow Creek in the Little Muddy valley (pl. 1), multiple terrace levels along Cow Creek (Howard, 1960), and a relatively greater thickness of drift north of Cow Creek than south.

The southern one-half of Williams County is sheet moraine. Sheet moraine is a blanket-like, thin deposit of drift, mostly till which does not mask the underlying topography (Kume, 1964). The contact between sheet moraine and ground moraine was arbitrarily determined and based on the relative abundance of drift mantled channels, drift mantled bedrock scarps and bedrock outcrops south of the contact.

Another temporary pause in the Charlson ice recession allowed the Cottonwood Creek melt-water channel (pl. 1 and fig. 23) and the McGregor melt-water channel to be cut.

Cottonwood Creek is a melt-water channel with steep sides and gravel deposits scattered along the channel walls. The gravel deposits have sloping and faulted bedding and are called kame terraces by Witkind (1959). Drainage from Cottonwood Creek probably ran both east and west as the ice pivoted around the bedrock high south of Hanks.

The McGregor end moraine is not very prominent and probably was deposited during a short still stand in the ice recession.

The ice margin continued to recede to the north stabilizing when the Grenora, Appam, and Hamlet end moraines were deposited (fig. 24). The glacier ice at this time probably did not recede much to the north but remained in place on the Missouri Coteau.

The Missouri Coteau escarpment acted as a barrier restricting the movement of the Late Wisconsinan ice to generally less than 30 miles. There was considerable shearing of the ice bringing debris up onto the ice surface. The debris insulated the ice slowing the melting. It was during this slow melting that much of the outwash was deposited in the Little Muddy valley (pl.1).

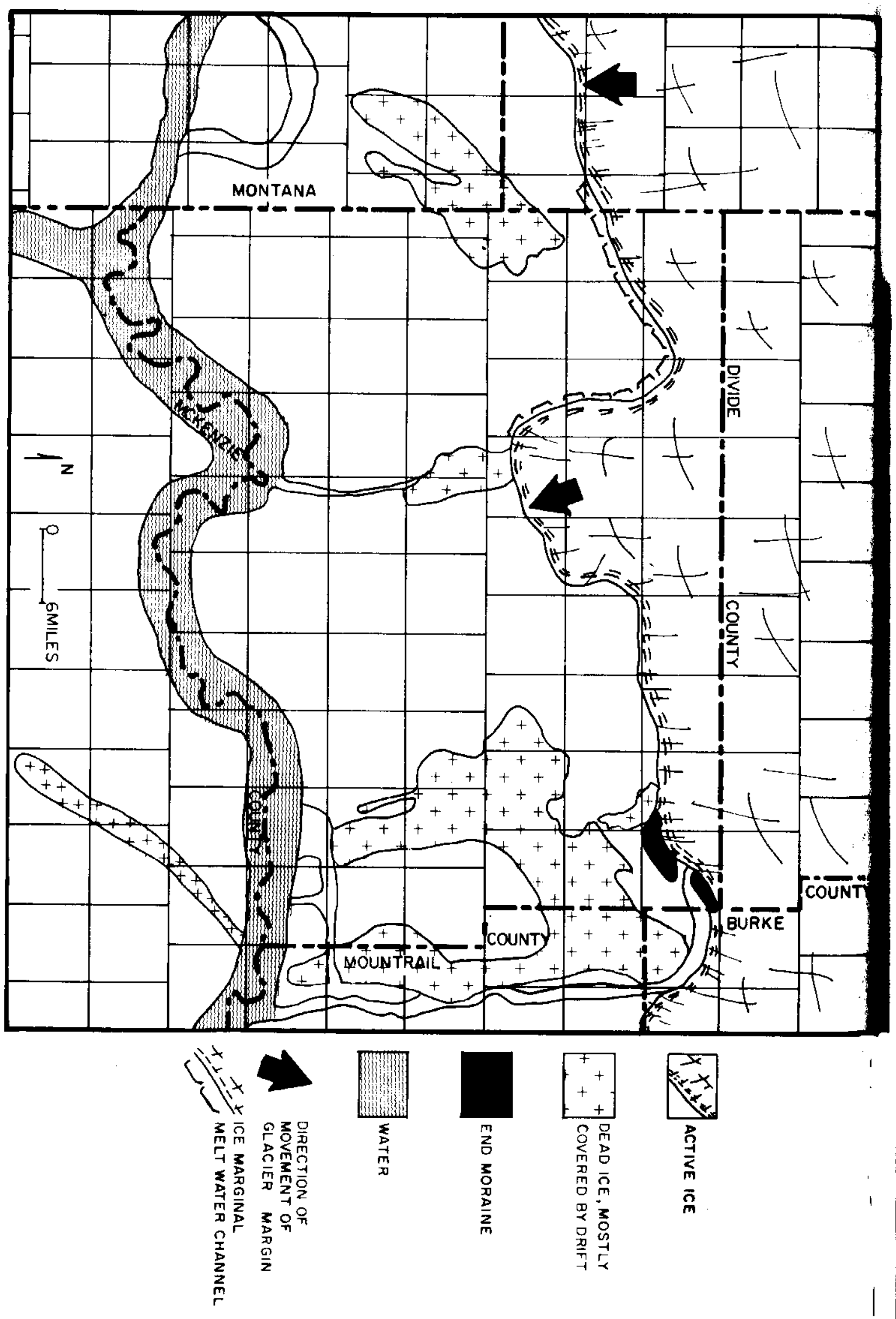

FIGURE 23. A short readvance of ice forming the McGregor end moraine.

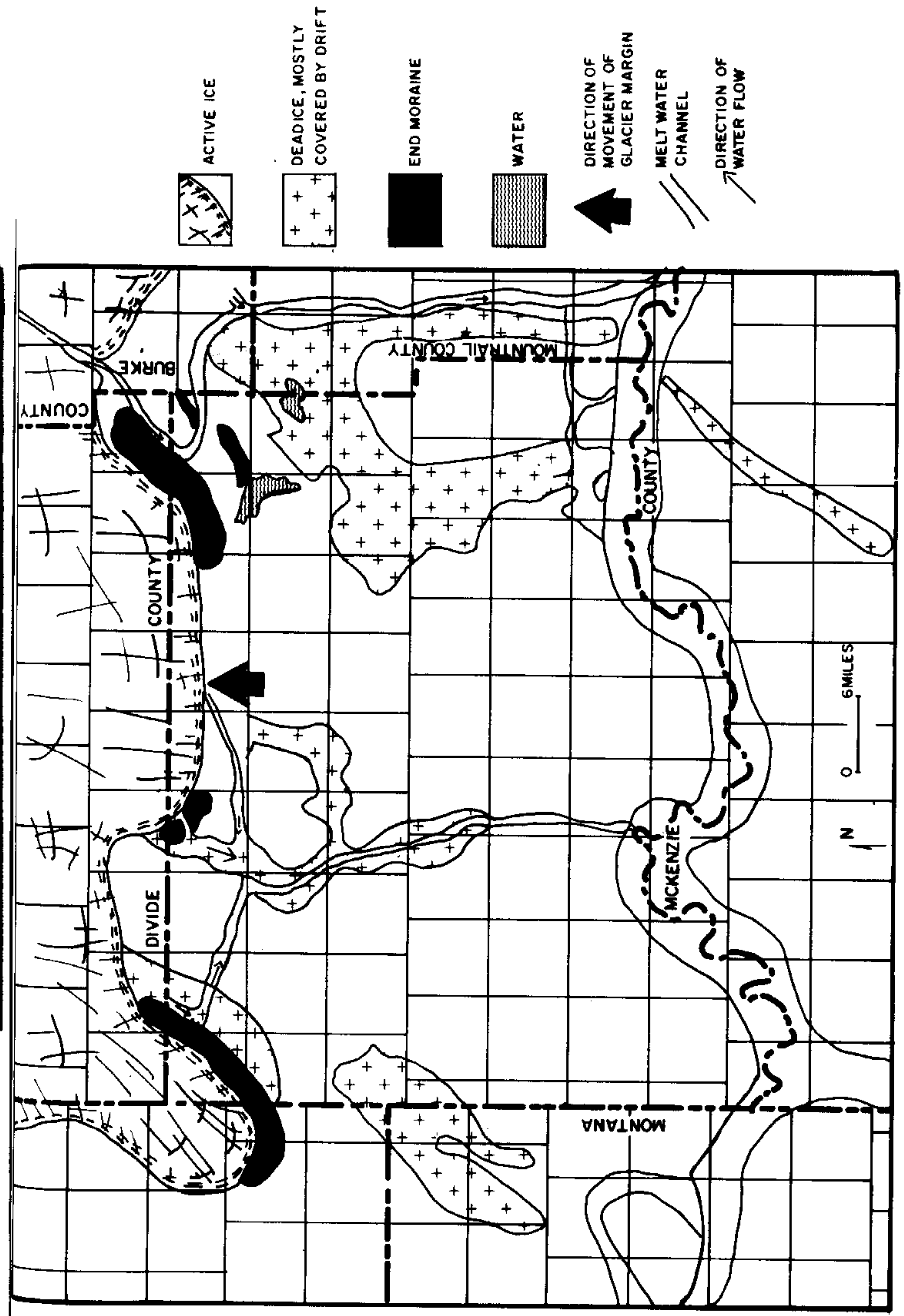

FIGURE 24. Final recession of the ice leaving the Grenora, Appam, and Hamlet end moraines.

ECONOMIC GEOLOGY

Petroleum

By far the most important economic resource in Williams Coun is petroleum. Oil was discovered in North Dakota in April, 1951, in t Clarence Iverson number 1, SW 1/4 SW 1/4 sec. 6, T. 155 N., R. 95 W along the Nesson anticline (pl. 1). Production of oil in Williams Coun through January 1, 1969 was 102,492,226 barrels of oil. The month production for the second half of 1968 was about 530,000 barre (North Dakota Geological Survey, 1968). All the oil in Willian County, except for about 12,000 barrels in a month from the Greno field, is produced from the Nesson anticline. Oil and gas productio comes from Mississippian, Devonian, Silurian, and Ordovician rock More detailed information can be found in other North Dako Geological Survey publications. A list of publications can be obtain from the North Dakota Geological Survey, Grand Forks, North Dakot

Lignite

Lignite, one of the most valuable resources, is found througho Williams County. Brant (1953) lists six major lignite beds in the count with an estimated total original reserve of 26,934,000 short tons. A present, there are only two lignite mines operating in Williams County the Cedar Coulee Mine number 2, a small underground mine with a annual production of about 615 tons, and the Nelson Pit, minin leonardite, producing 4,600 tons per year (Easton, 1967). The Gre Northern Railway Company has explored the lignite deposits in th Williston basin and has reports on prospects in Williams County whic are available at the North Dakota Geological Survey office, Gran Forks, North Dakota, or the Great Northern Railway station Williston, North Dakota.

Lignite beds found during this study are fairly persistent. (S section on lignite under Tongue River and Sentinel Butte Formations At several locations along the Missouri River, lignite beds are foun directly under the glacial deposits. The glacial deposits are generally thin along the Missouri River, and most of the lignite beds directly beneath the glacial deposits are leonardite. The leonardite mined in the Nelson Pit, mentioned above, is of this type.

Throughout the southern part of the county are many abandoned coal mines which were mined primarily by the landowner for his own use. Near Hanks are several abandoned underground mines which supplied coal for local use.

Plate 3 has a fair representation of the lignite beds found in southern Williams County. These beds are exposed along the Missouri River and are fairly flat lying except near the Nesson anticline.

Halite or Rock Salt

Salt is presently being mined by the Dakota Salt and Chemical Company at Williston. This salt is mined hydraulically from the Mississippian "A" salt (Anderson and Hansen, 1957) which is 230 feet thick at a depth of 8,000 feet. Production in 1964 was about 200 tons per day.

Clay

Clay deposits are extensive in the Fort Union beds of Williams County. On Plate 3, all the beds which are bentonitic are represented by the symbol B. An unpublished study by Oscar E. Manz, Ceramic Engineer with the North Dakota Geological Survey in 1961, indicates that some of the clays are suitable for ceramic products.

Sand and Gravel

Sand and gravel deposits of various sizes are present in most areas of Williams County. The gravels indicated by yellow on Plate 1 are the best sorted (graded) and are of glacial origin. The gravels indicated by Qw on Plate 1, north and west of Williston are western gravels high in chert and quartz and low in shale. The gravel deposits, colored red on Plate 1, are the least sorted (graded).

"Scoria"

"Scoria" or baked sediment deposits are often mined for use as a road surfacing material on the roads to oil wells. "Scoria" is found at Hanks, Bull Butte, and along the Missouri River. Plate 1, the geologic map, has symbols representing the "Scoria" pits seen during this study.

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NORTH DAKOTA GEOLOGICAL SURVEY
NORTH DAKOTA STATE WATER COMMISSION

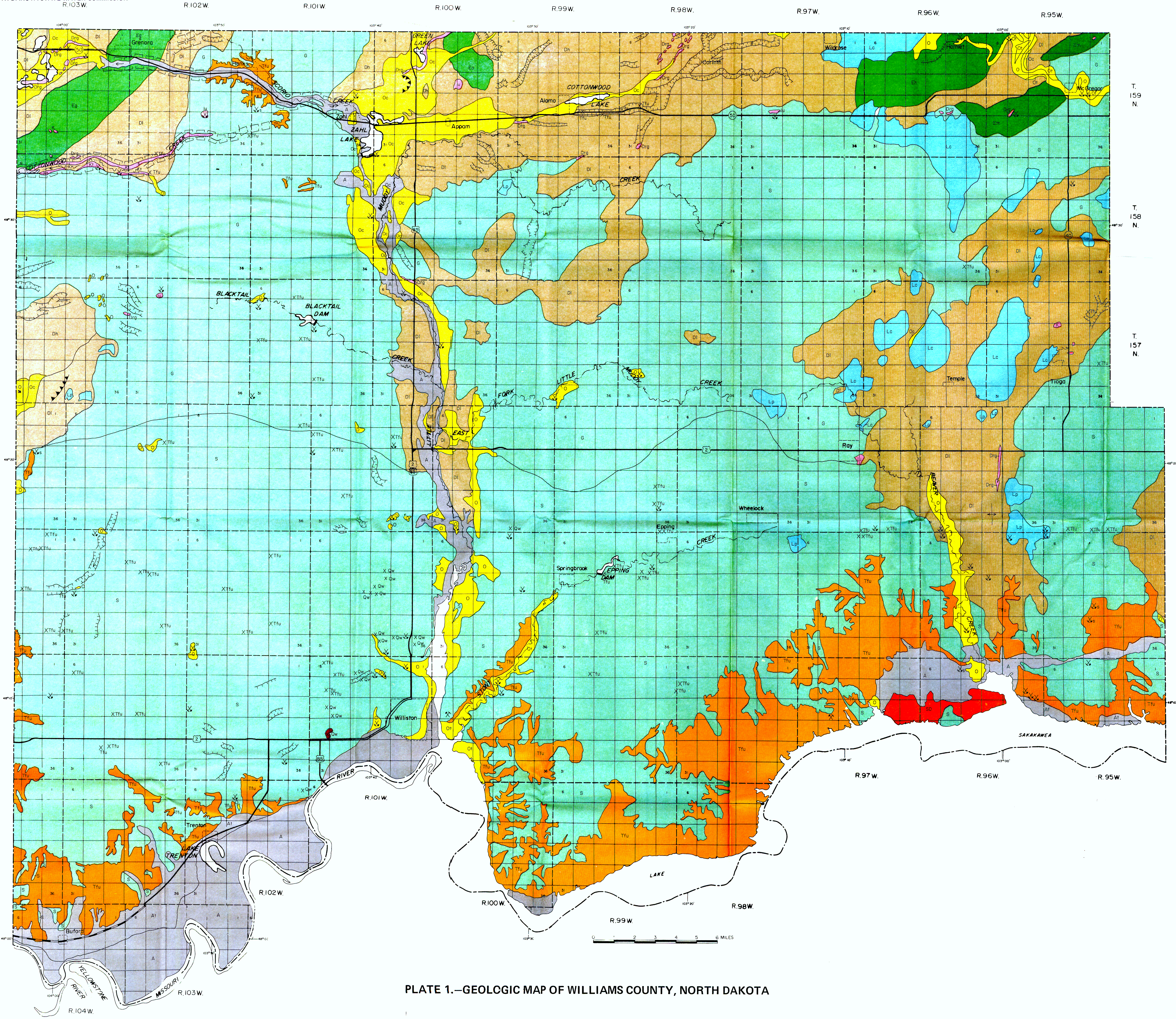


PLATE 1.—GEOLOGIC MAP OF WILLIAMS COUNTY, NORTH DAKOTA

Base prepared from North Dakota State Highway Department county highway maps

EXPLANATION

GLACIAL LANDFORMS

Ea — APPAM END MORAINE
A CURVED, LOOP-SHAPED RIDGE OF DRIFT WITH MANY SMALL SUPERIMPOSED LINEAR RIDGES. COMPOSED CHIEFLY OF TILL. THE MORAINE IS ABOUT 3 MILES LONG AND 1.5 MILES WIDE WITH MEDIUM TO HIGH LOCAL RELIEF (25 TO 100 FEET BETWEEN ADJACENT HIGHS AND LOWS).

Eg — GRENORA END MORAINE
AN AREA OF SMALL LINEAR RIDGES AND SOME DEAD-ICE MORAINE FEATURES EXTENDING FROM GRENORA SOUTHWEST TO THE MONTANA LINE. COMPOSED MOSTLY OF TILL AND HAS LOW TO HIGH (10 TO 50 FEET) LOCAL RELIEF.

Eh — HAMLET END MORAINE
A BAND OF LOW PARALLEL RIDGES WITH SOME DEAD-ICE FEATURES EXTENDING FROM HAMLET 5 MILES TO THE SOUTHWEST. LOCAL RELIEF IS LOW (LESS THAN 20 FEET). COMPOSED MOSTLY OF TILL.

Em — McGREGOR END MORAINE
A NORTHEAST-SOUTHWEST TRENDING BAND OF LOW RIDGES NORTHWEST OF McGREGOR. RELIEF IS LOW, BUT THE RIDGES CAN BE DISTINGUISHED ON THE AERIAL PHOTOS.

Dh — DEAD-ICE MORAINE (HIGH-RELIEF)
HILLS, KNOBS, SLOUGHS, KETTLES, RIDGES, TRENCHES, AND MANY DEAD-ICE FEATURES. RIDGES MAY BE PRESENT AS IN AN END MORAINE, BUT THERE IS NO OVERALL TREND OF ACTIVE-ICE LINEAR FEATURES. TILL IS THE PRIMARY CONSTITUENT, BUT SMALL AREAS OF SAND AND/OR GRAVEL CAN BE FOUND THROUGHOUT THE AREA. LOCAL RELIEF RANGES FROM 25 TO 150 FEET. GENERALLY THERE IS NON-INTEGRATED DRAINAGE.

Dl — DEAD-ICE MORAINE (LOW-RELIEF)
SAME AS HIGH RELIEF DEAD-ICE MORAINE EXCEPT THAT THE LOCAL RELIEF IS GENERALLY LESS THAN 50 FEET. THERE IS SOME INTEGRATED DRAINAGE.

G — GROUND MORAINE
A FLAT TO GENTLY ROLLING DRIFT PLAIN CONSISTING MAINLY OF TILL. LOCAL RELIEF IS LOW (LESS THAN 15 FEET).

S — SHEET MORAINE
A THIN SHEET OF GLACIAL DRIFT DRAPED OVER THE PRE-EXISTING TOPOGRAPHY AND REFLECTING MUCH OF THE UNDERLYING TOPOGRAPHY. COMPOSED MOSTLY OF TILL. OCCURS IN THE SOUTHERN 1/4 TO 1/2 OF WILLIAMS COUNTY.

Oc — OUTWASH PLAIN, COLLAPSED
A HILLY AREA UNDERLAIN PRIMARILY BY SAND AND GRAVEL. LOW TO HIGH LOCAL RELIEF (10 TO 75 FEET) WITH SOME KETTLES.

Lc — LAKE PLAIN, COLLAPSED
A GENTLY ROLLING TO HILLY AREA OF LAKE DEPOSITS, MOSTLY OF CLAY AND SILT. LOCAL RELIEF IS LOW (LESS THAN 15 FEET).

K — KAME
A MOUND OR HILL OF STRATIFIED SAND AND GRAVEL.

Kt — KAME TERRACE
A LINEAR DEPOSIT OF STRATIFIED DRIFT, PREDOMINATELY SAND AND GRAVEL, PRESENT ALONG THE WALLS OF COTTONWOOD CREEK MELTWATER CHANNEL.

Iu — ICE CONTACT DEPOSIT UNDIFFERENTIATED
AN IRREGULAR-SHAPED DEPOSIT OF DRIFT, MOSTLY SAND AND GRAVEL BUT WITH SOME TILL.

Drg — DISINTEGRATION RIDGE, GRAVEL
A NARROW, STEEP-SIDED RIDGE OF SAND AND GRAVEL. MAY BE SEGMENTED OR CONTINUOUS AND STRAIGHT OR SINUOUS.

Drt — DISINTEGRATION RIDGE, TILL
A NARROW STEEP SIDED RIDGE OF TILL.

DRIFT-MANTLED BEDROCK SCARP
A STEEP ABUTMENT ON THE GROUND MORAINE OR SHEET MORAINE UNDERLAIN BY THIN GLACIAL DEPOSITS OVER A BEDROCK SCARP.

DRIFT-MANTLED CHANNEL OR KETTLE CHAIN
A LINEAR DEPRESSION UNDERLAIN BY TILL. STEEP SIDED IN THE AREAS OF GROUND MORAINE AND DEAD-ICE MORAINE.

ICE CONTACT FACE
A STEEP ABUTMENT OF GLACIAL DRIFT.

PROGLACIAL LANDFORMS

O — OUTWASH PLAIN
A GENTLY UNDULATING TO NEARLY FLAT SURFACE UNDERLAIN BY SAND AND GRAVEL WITH SOME SILT AND CLAY. COMMONLY STRATIFIED.

Ot — OUTWASH TERRACE
A NEARLY LEVEL, BENCHLIKE, WATER-DEPOSITED ACCUMULATION OF SAND AND GRAVEL, SANDY GRAVEL, GRAVELLY SAND WITH A FEW BOULDERS AND COBBLES.

Lp — LAKE PLAIN
GENTLY UNDULATING TO FLAT DEPOSIT OF CLAY, SILT AND SOMETIMES SAND AND GRAVEL, GENERALLY STRATIFIED.

MELTWATER CHANNEL
A STEEP-SIDED TRENCH THAT CARRIED MELTWATER FROM A GLACIER; MAY BE UNDERLAIN BY SAND, GRAVEL OR TILL. ARROW SHOWS THE DIRECTION OF THE MOST RECENT FLOW OF MELTWATER.

NONGLACIAL LANDFORMS

A — ALLUVIAL FLOODPLAIN
A LEVEL TO GENTLY UNDULATING ACCUMULATION OF STREAM DEPOSITS THAT ARE GENERALLY STRATIFIED AND ADJACENT TO A STREAM. UNDERLAIN BY INTERBEDDED CLAY, SILT, SAND, GRAVEL AND SOME ORGANIC DEBRIS.

At — ALLUVIAL TERRACE
A FLAT OR GENTLY SLOPING BENCH ABOVE AND ADJACENT TO THE FLOODPLAIN OF THE MISSOURI RIVER. UNDERLAIN BY INTERBEDDED CLAY, SILT, SAND, GRAVEL AND ORGANIC DEBRIS.

SD — SAND DUNES
AN AREA OF AEOLIAN SAND DEPOSITS CHARACTERIZED BY LOW MOUNDS OF SAND AND BLOWOUTS.

NAMED FORMATIONS

Qw — QUATERNARY WIOTA GRAVEL
FINE TO MEDIUM SAND AND SANDY GRAVEL CONSISTING OF 70 TO 80 PERCENT CHERT AND QUARTZITE. REDDISH BROWN TO BROWN. OVERLAIN BY TILL IN WILLIAMS COUNTY.

Tfu — TERTIARY FORT UNION GROUP
TONGUE RIVER-SENTINEL BUTTE FORMATIONS UNDIFFERENTIATED. EXPOSED IN THE AREA OF STUDY, BUT THE CONTACT BETWEEN THE TWO FORMATIONS HAS NOT BEEN ESTABLISHED. CONSISTS OF CLAY, SILT, SAND AND LIGNITE BEDS. COLORS RANGE FROM LIGHT GRAY TO YELLOWISH GRAY TO YELLOW.

SYMBOLS

LIGNITE MINE

GRAVEL PIT (GLACIAL GRAVELS)

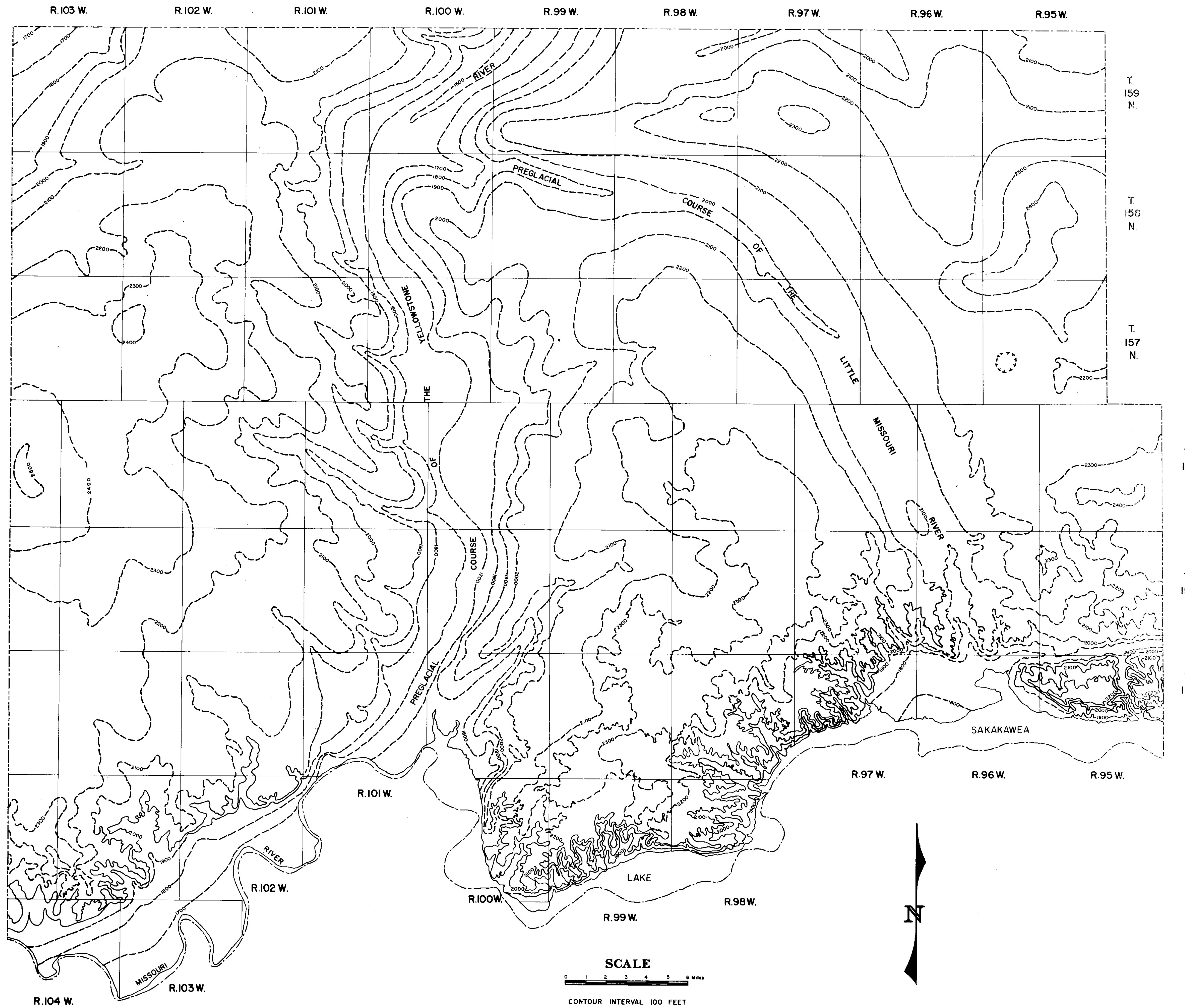
Qw — GRAVEL PIT (WIOTA GRAVEL, BROWN, QUARTZITIC

s — GRAVEL PIT ("SCORIA ROCK")

NESSON ANTICLINE

NORTH DAKOTA GEOLOGICAL SURVEY
NORTH DAKOTA STATE WATER COMMISSION

BULLETIN 48
COUNTY GROUND WATER STUDIES 9
PLATE 2



SCALE

0 1 2 3 4 5 6 Miles

CONTOUR INTERVAL 100 FEET

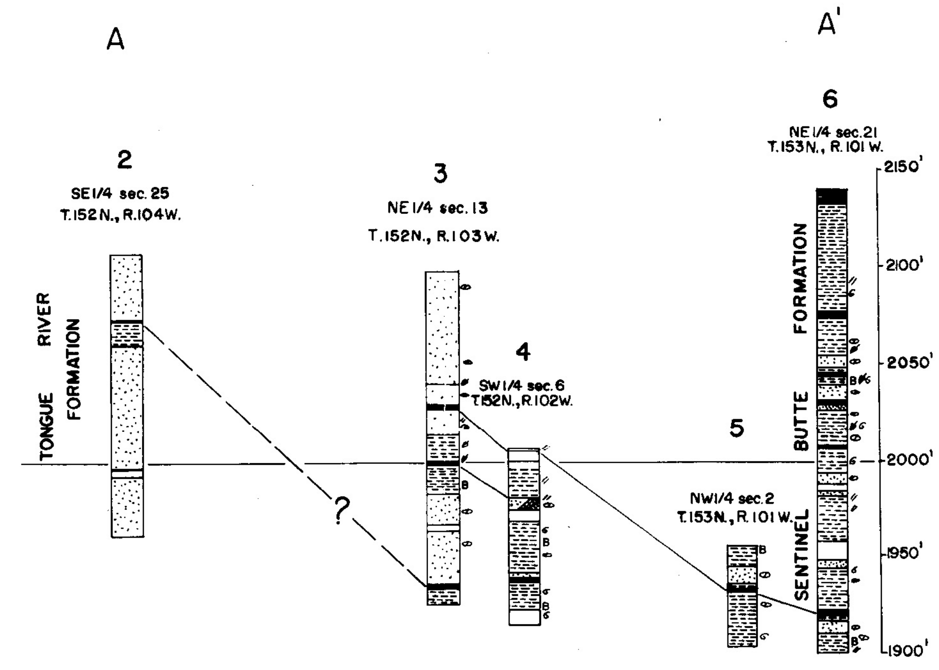
——— SUBSURFACE CONTOUR

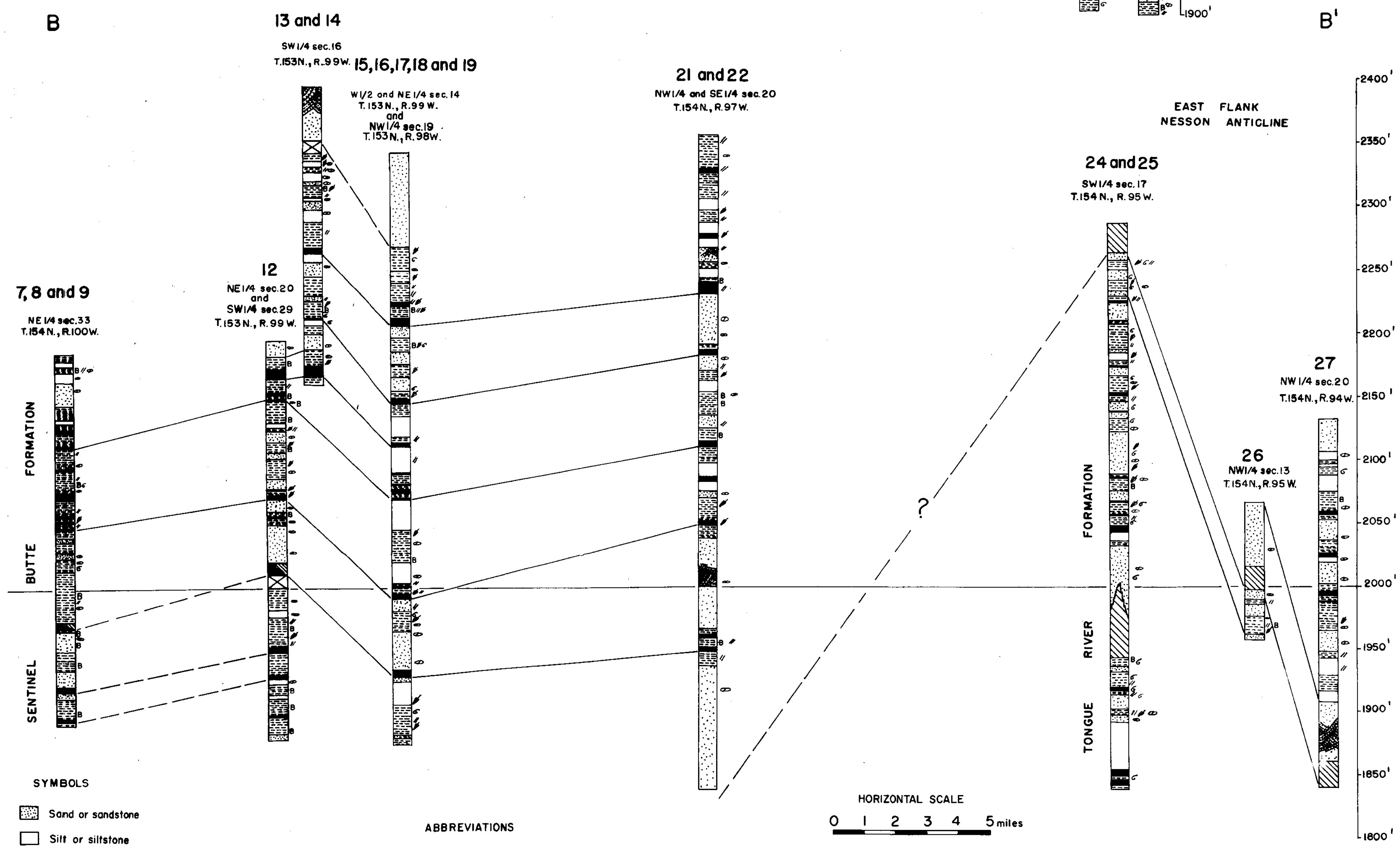
——— SURFACE CONTOUR

Modified From Armstrong, C.A., Geology and ground water resources of Williams County, Part III, Ground Water Hydrology: North Dakota Geological Survey Bull. 48

BEDROCK TOPOGRAPHY OF WILLIAMS COUNTY, NORTH DAKOTA

Stratigraphic Cross-Sections Along The Missouri River From The Yellowstone River To The Mountrail-Williams County Line



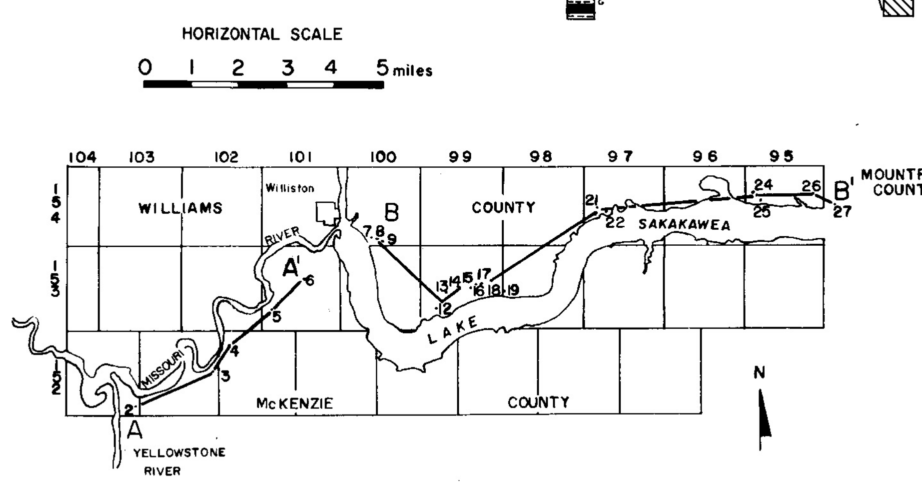


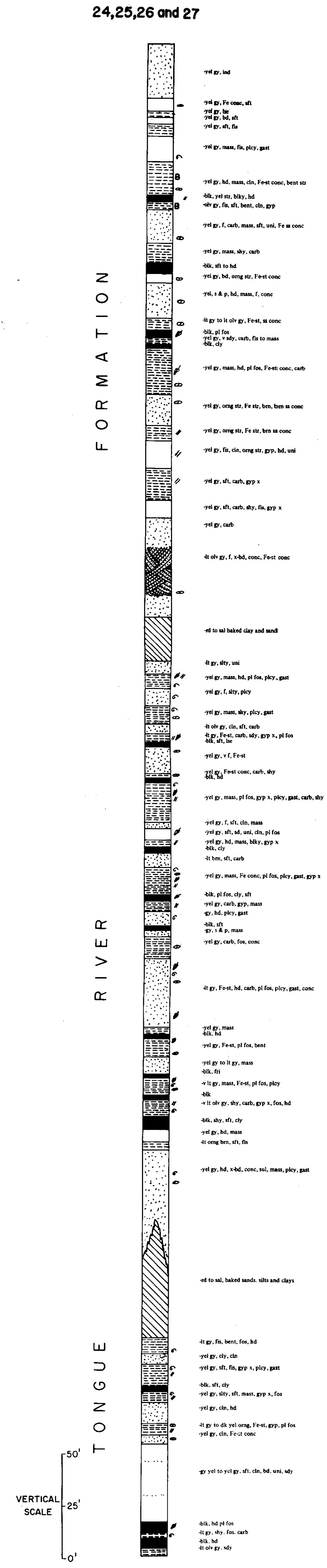
SYMBOLS

- Sand or sandstone
- Silt or siltstone
- Shale, clay or claystone
- Lignite
- Lignite or "scoria"
- "Scoria"
- Concretions
- Gastropods and pelecypods
- Plant fossils
- Bentonitic
- Gypsiferous
- Covered, no description

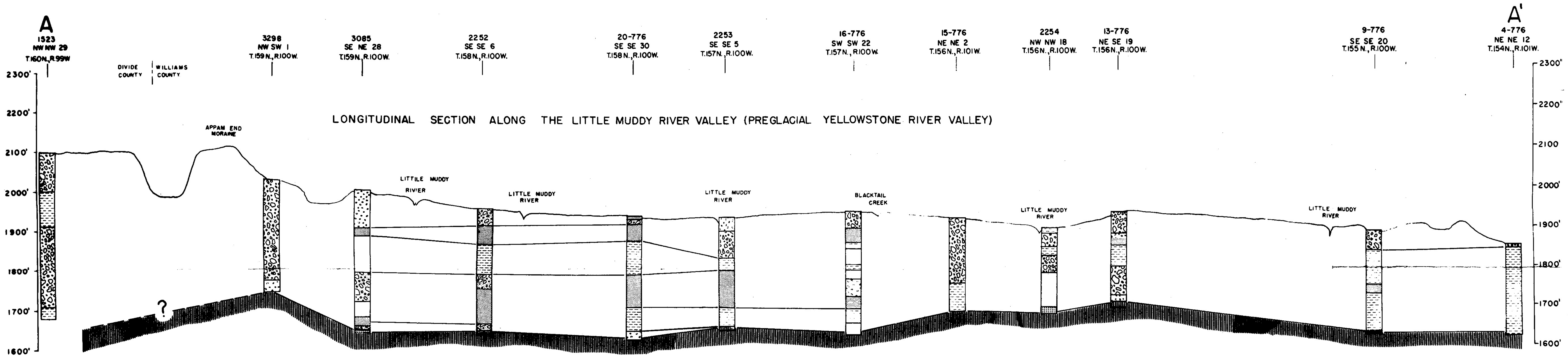
ABBREVIATIONS

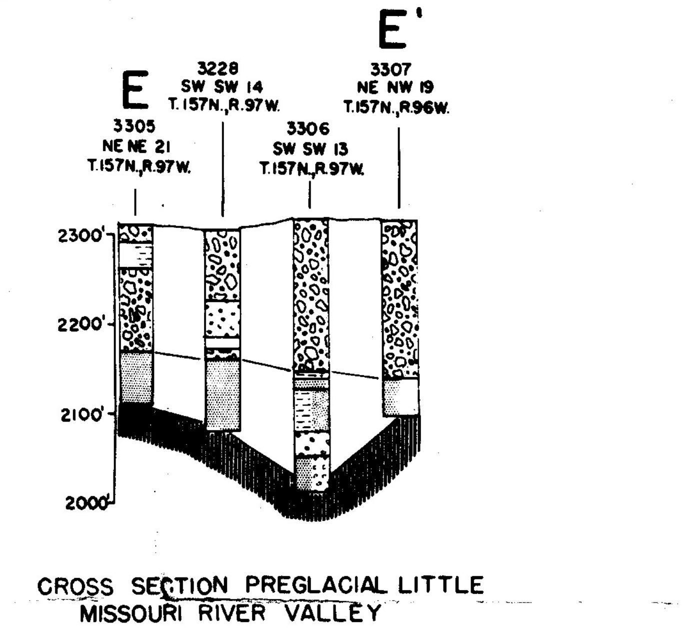
bd	bedded or bedding	lt	light
bent	bentonite or bentonitic	lse	loose
bf	buff	mass	massive
blk	black	olv	olive
blky	blocky	orng	orange
brn	brown or brownish	plcy	pelecypods
carb	carbonaceous	pl fos	plant fossils
cln	clean	rd	red
conc	concretion(s)	sal	salmon
dk	dark	sdy	sandy
f	fine	sft	soft
Fe	Ferrouginous	shy	shaley
Fe-st	ironstone	slty	silty
fis	fissile	s&p	salt and pepper appearance
fos	fossils	ss	sandstone
fri	friable	str	streaked
gast	gastropods	uni	uniform
gy	gray	v	very
gyp	gypsum	x	crystal(s)
hd	hard	x-bd	crossbedded
ind	indurated	yel	yellow

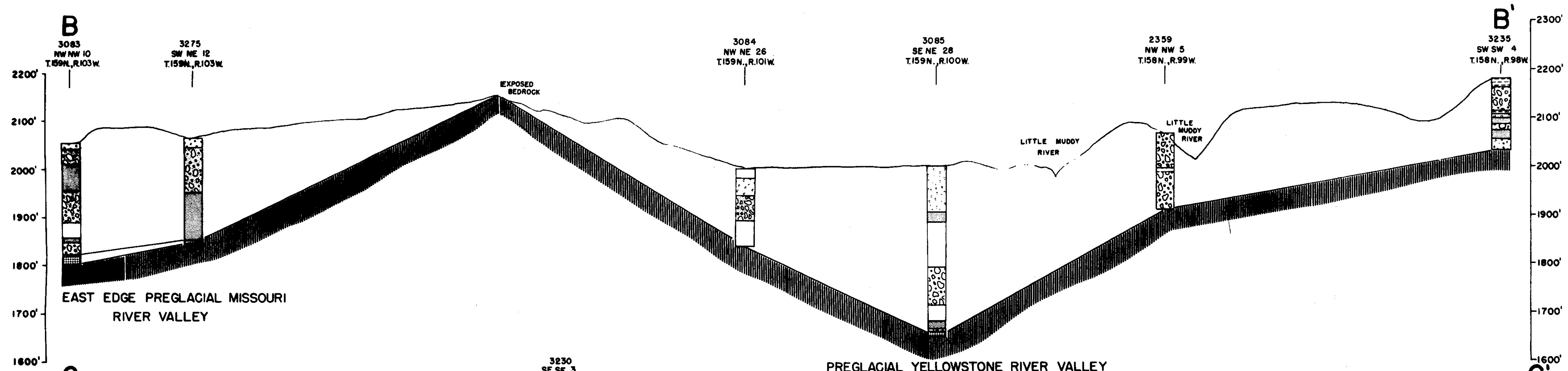


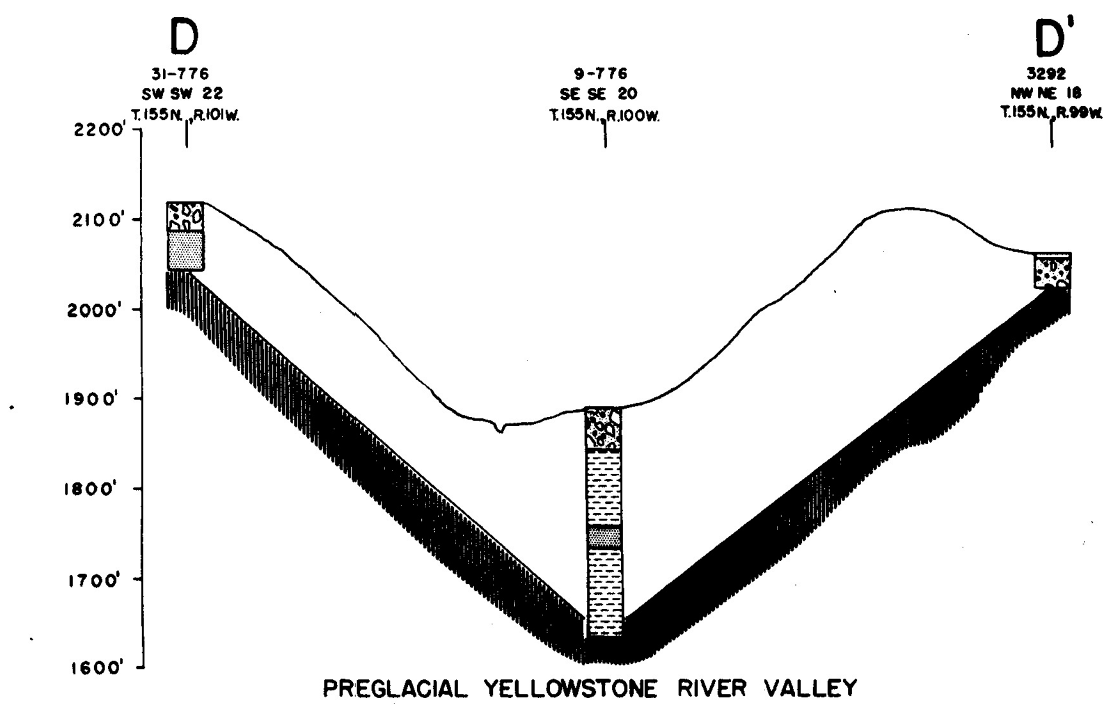


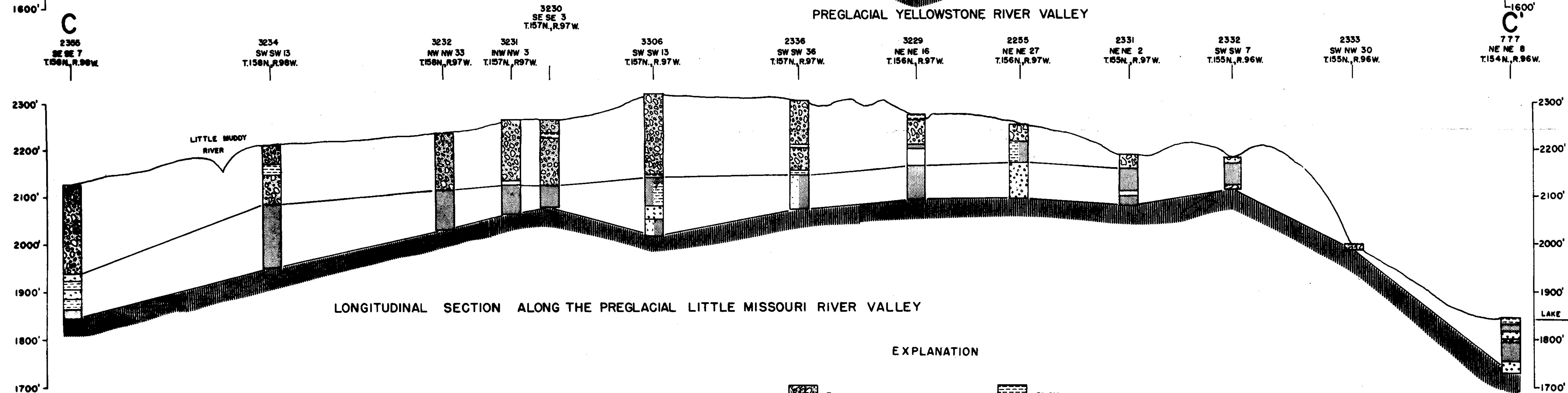
GEOLOGIC SECTIONS OF GLACIAL DRIFT IN WILLIAMS COUNTY, NORTH DAKOTA

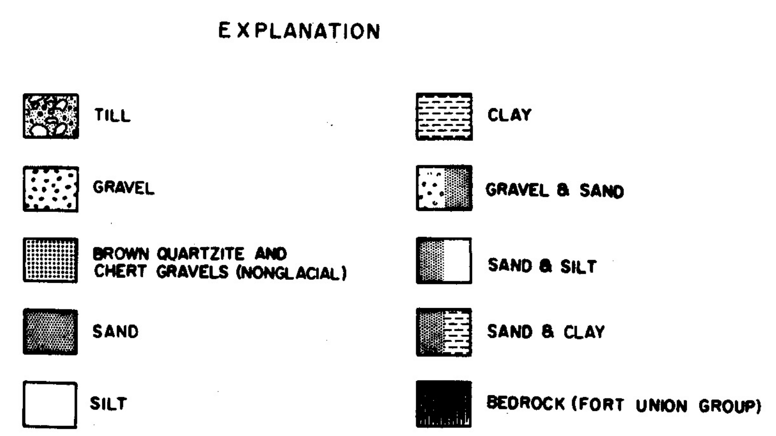












Configuration of ground surface based on Army Map Service Quadrangle NM 13-12 Williston, scale 1:250,000, contour interval 100'.

All well data (except for Divide County well 1523) is available in North Dakota Geological Survey Bull. 48, Geology and Ground Water Resources of Williams County, North Dakota, Part-II Basic Data by Clarence Armstrong.