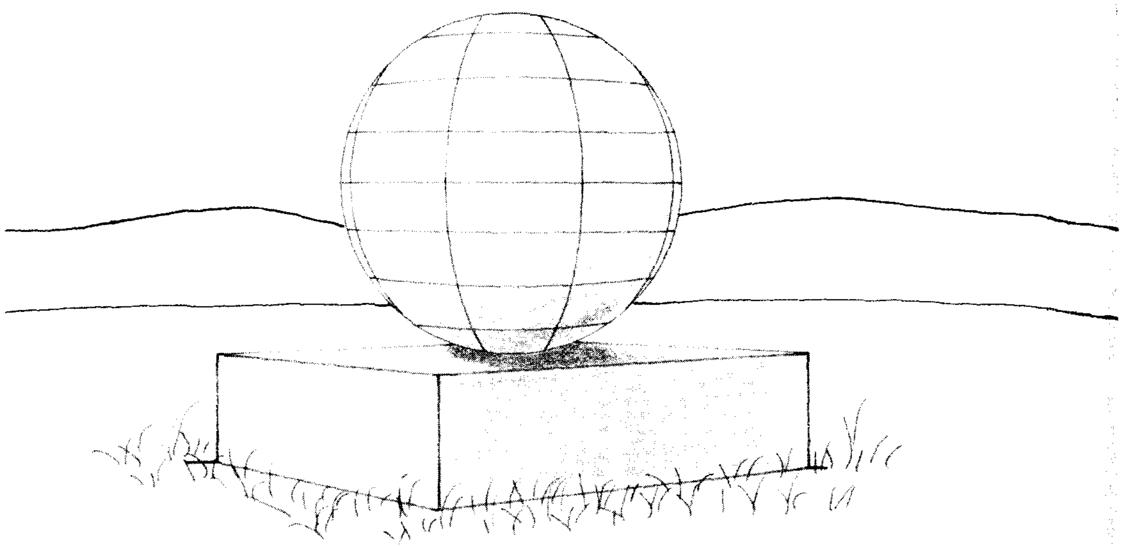
GEOLOGY
of
McHENRY COUNTY
NORTH DAKOTA



John P. Bluemle

BULLETIN 74--PART I
NORTH DAKOTA GEOLOGICAL SURVEY
Grand Forks, North Dakota
1982

The drawing on the cover represents a memorial to David Thompson, an English geographer, who in 1797 explored and mapped the Souris and Missouri Rivers. The monument, which consists of a six-foot diameter sphere of granite mounted on a granite pedestal, is located near Verendrye in McHenry County.

GEOLOGY

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McHENRY COUNTY, NORTH DAKOTA

by
John P. Bluemle
North Dakota Geological Survey
Grand Forks, North Dakota
1982

BULLETIN 74—PART I
North Dakota Geological Survey
Don L. Halvorson, *State Geologist*

COUNTY GROUNDWATER STUDIES 33—PART I
North Dakota State Water Commission
Vernon Fahy, *State Engineer*

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in cooperation with the U.S. Geological Survey,
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and the McHenry County Water Management District

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ABSTRACT

McHenry County, located on the eastern side of the Williston Basin, is underlain by 6,000 to 8,600 feet of Paleozoic, Mesozoic, and Cenozoic rocks that dip to the west toward the center of the basin about a hundred miles to the southwest. The Cretaceous Pierre, Fox Hills, and Hell Creek Formations and the Tertiary Cannonball and Bullion Creek Formations lie directly beneath the glacial drift. Bullion Creek sandstone beds are exposed in places along the Missouri Escarpment in southwestern McHenry County. The Pleistocene Coleharbor Group, which covers the entire area, averages about 100 feet thick, reaching a maximum of about 450 feet. The Holocene Oahe Formation occurs in sloughs throughout the county, on river bottomland, and in large dunes over much of the glacial Lake Souris plain.

McHenry County is located mainly on the Glaciated Plains, an area of undulating to flat topography. Ice-thrust and fluted topography are common in the southern part of the county. Much of the northern half of the county is part of the glacial Lake Souris plain, an area that has been greatly modified by the wind and is now largely covered by extensive dune fields. The southwesternmost corner of the county is part of the Missouri Coteau, an area characterized by hilly, collapsed glacial sediment with numerous sloughs, lakes, and closely spaced hills.

INTRODUCTION

Purpose

This report is published by the North Dakota Geological Survey in cooperation with the North Dakota State Water Commission, the United States Geological Survey, and the McHenry County Water Management District. It is one of a series of county reports on the geology and groundwater resources of North Dakota. The main purposes of these studies are: 1) to provide a geologic map of the area; 2) to locate and define aquifers; 3) to determine the location and extent of mineral resources in the counties; and 4) to interpret the geologic history of the area. This volume describes the geology of McHenry County. Readers interested in groundwater should refer to Part II of this bulletin, which includes detailed basic data on the groundwater, and Part III, which is a description and evaluation of the groundwater resources of McHenry County.

Parts of this report that are primarily descriptive include the discussions of the topography, rock, and sediment in McHenry County. This information is intended for use by anyone interested in the physical nature of the materials underlying the area. Such people may be water-well drillers or hydrologists interested in the distribution of sediments that have potential to produce usable groundwater; civil engineers and contractors interested in such things as the gross characteristics of foundation materials at possible construction sites, criteria for selection and evaluation of waste disposal sites, and the locations of possible sources of borrow material for concrete aggregate; industrial concerns looking for possible sources of economic minerals; residents interested in knowing more about the area; and geologists interested in the physical evidence for the geologic interpretations.

Previous Work

All or portions of McHenry County have been included in several previous studies. In 1883, Chamberlin presented a map of the Missouri Coteau in "Terminal Moraines of the Second Glacial Epoch." Todd (1896) described the moraines of the Missouri Coteau. Leonard (1916) described the "pre-Wisconsin drift" of North Dakota. He placed the western limit of the Wisconsinan drift at the front of the "Altamont Moraine." Andrews (1939) discussed the development of several spillways that drained water from glacial Lake Souris into the Sheyenne River. Lemke (1960) included all but the eastern quarter of McHenry County in a report on the Souris River area. A study of the geology of the Drake Quadrangle was completed in 1950 by L. F. Jenkinson as an unpublished Master's thesis at the State University of Iowa.

Several geologic reports of the present county series are now available for the area near McHenry County. They include McLean County (Bluemle, 1971); Pierce County (Carlson and Freers, 1975); and Sheridan County (Bluemle, 1981). Fieldwork is currently underway in Bottineau County.

The North Dakota State Water Commission has published reports on the geology and groundwater resources of three areas in McHenry County: the Upham area (Paulson and Powell, 1957); the Drake area (Adolphson, 1961); and the Crosby-Mohall area (LaRoche, Swenson, and Greenman, 1963).

A soil survey of McHenry County was published in 1925 (Knobel and others).

Methods of Study

During the 1969 and 1970 field seasons, S. R. Moran, then a North Dakota Geological Survey geologist, mapped the geology of McHenry County. Moran examined aerial photographs and soils maps of the county and field checked at many locations. A large number of auger holes, averaging about 50 feet deep, were drilled in McHenry County under Moran's supervision. Additional information on near-surface materials was obtained from Highway Department borings.

Moran compiled a geologic map of McHenry County in 1970, and it is his map that forms the basis for the geologic map (pl. 1) that is included with this report.

During the 1979 field season, I checked Moran's geologic map of McHenry County and made some minor revisions. Most of the lithologic information on Moran's map was accepted without change. At the time Moran studied McHenry County, the cooperative groundwater study was not yet underway, and no decision was made to proceed with publishing a report on the geology of the county.

In 1971 a formal study was undertaken and the State Water Commission initiated an intensive test drilling program. Nearly 40,000 feet of test drilling was completed in McHenry County in 1976-1978. In addition to drilling undertaken as part of the county groundwater study, 50,000 feet of additional drilling has been incorporated into the study. Some of this is earlier Water Commission test drilling; some is by the Bureau of Reclamation (now the Water and Power Resources Service) (approximately 7,000 feet); some by the North Dakota Geological Survey (approximately 750 feet); some was done as part of the test drilling program prior to installing the Minuteman missiles (about 1,000 feet); and the remainder was mainly by local water-well drillers (over 20,000 feet).

Regional Topography and Geology

McHenry County, in central North Dakota, has an area of 1,890 square miles in Townships 151-159 North and Ranges 75-80 West. It is located between 100° 11' 51" West Longitude on the east and 101° 3' 33" West Longitude on the west; 47° 50' 52" North Latitude on the south and 48° 37' 57" North Latitude on the north.

The Glaciated Plains cover all of McHenry County except for the southwesternmost corner of the county, about 30 square miles, which is on the Missouri Coteau (figs. 1 and 2). The Glaciated Plains can be subdivided into two areas: the broad glacial Lake Souris plain over approximately the northeast 60 percent of the county and an expanse of till to the south of the lake plain. Much of the lake plain area has been modified by wind erosion and parts of it are covered by extensive dune deposits. The till plain, which lies south and west of the lake plain, is highly fluted in places and includes outstanding drumlin-like features (long, linear ridges) in the Verendrye and Balfour areas.

Most of McHenry County has only low to moderate relief. Relief is highest over areas of dunes, where it may be 50 to 100 feet locally and on some of the ice-thrust hills in the southern part of the county, where it exceeds 100 feet in places. Elevations average near 1,600 feet over the till plain and range between 1,450 and 1,500 feet over much of the glacial Lake Souris plain. The highest elevations are over 2,000 feet on the Missouri Coteau in the southwest corner of the county, and the lowest is about 1,420 feet where the Souris River leaves the county.

McHenry County is situated on the east flank of the Williston Basin, an intracratonic, structural basin containing a thick sequence of sedimentary rocks. All the formations below the Coleharbor have a westerly to west-southwesterly regional dip that ranges from 60 feet per mile in the lowermost Paleozoic rocks to 50 feet per mile at the top of the Devonian and less than 20 feet per mile in the upper Cretaceous sediments.

STRATIGRAPHY

General Statement

As much as 8,600 feet of Paleozoic, Mesozoic, and Cenozoic sedimentary rocks lie on the Precambrian basement in McHenry County. The discussion that follows is mainly a description of the composition, sequence, and correlation of the geologic units that lie at and immediately beneath the surface in McHenry County. The description proceeds from the oldest known mate-

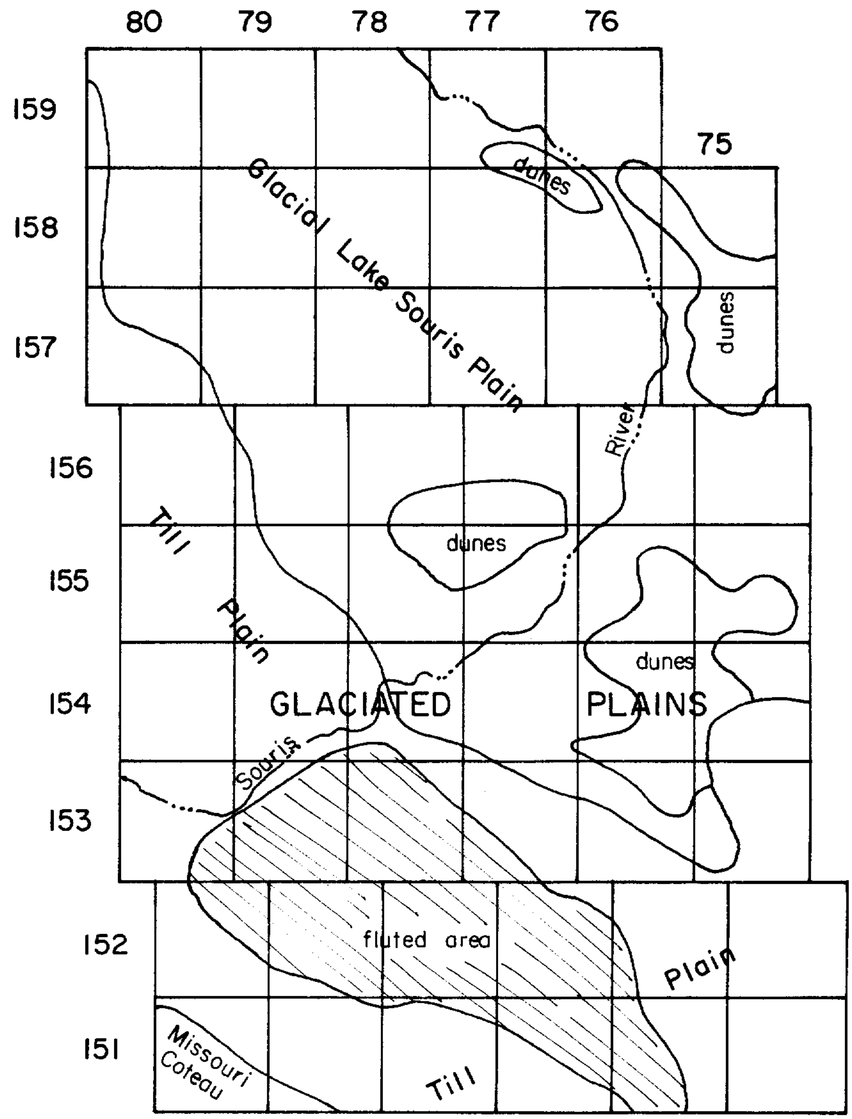


Figure 1. Physiographic map of McHenry County.

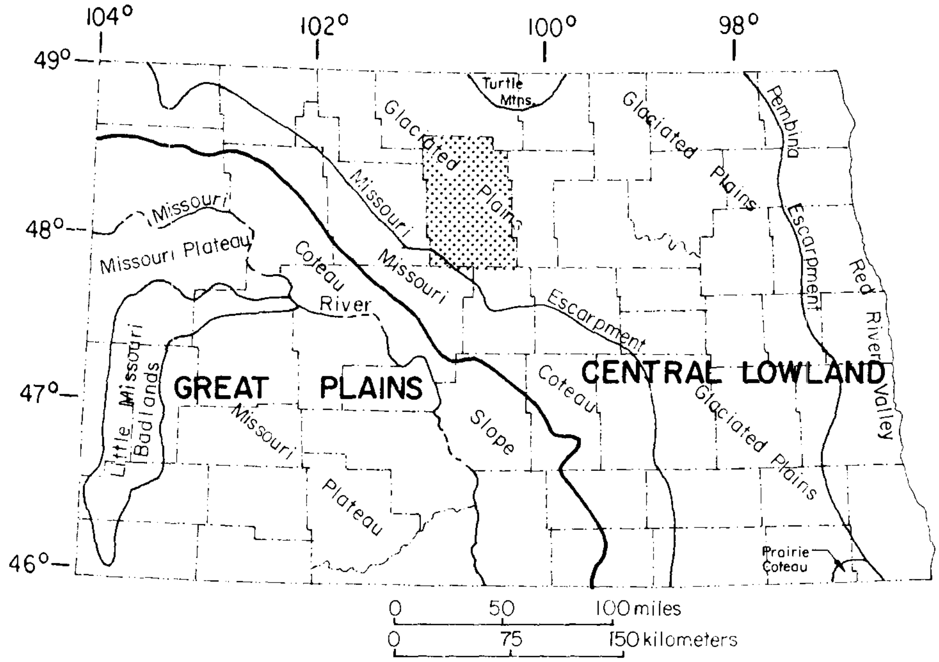


Figure 2. Physiographic map of North Dakota showing the location of McHenry County.

rials, which are discussed briefly, to the younger materials. The younger, more easily accessible geologic units are described in much greater detail than are the older units. All of the landforms that occur at the surface in McHenry County are composed of Pleistocene materials, which were deposited mainly by glacial action. Considerable attention will be given to the configuration and origin of these landforms.

Precambrian Rocks

Based on information obtained from the single test hole that has been drilled to the Precambrian in McHenry County and from Precambrian tests in nearby areas, it appears that the Precambrian surface slopes west-southwestward toward the center of the Williston Basin at about 60 to 65 feet in a mile. The Precambrian surface ranges from about 6,000 feet deep in northwestern McHenry County to about 8,600 feet in the southwest corner of the county.

The only test hole that penetrated Precambrian rocks in McHenry County (NE¼SW¼ sec 3, T157N, R78W), bottomed in biotite granite at a depth of 7,174 feet. The rock consisted of 35 percent quartz, 34 percent calcic plagioclase, 23 percent microcline microperthite, 6 percent biotite, and small amounts of sphene, apatite, and muscovite. It had an allotrimorphic granular texture. The cuttings were small, but the minerals appeared to be fine grained. The quartz was mildly strained. Perthitic lamellae in the microcline ranged from sparse to abundant. Sericite and epidote patches varied in amount in the plagioclase. The brown biotite was locally chloritized and the opaques were unaltered.

E. G. Lidiak, in an unpublished manuscript, has included the McHenry County Precambrian sample in his "Towner Granite Terrane." Lidiak suggested that the granitic rocks of the Towner Granite Terrane occur in a transitional zone separating early and middle Precambrian rocks.

Paleozoic Rocks

Paleozoic rocks range in thickness from about 3,200 feet in the eastern part of McHenry County to about 4,200 feet in the northwest corner. For purposes of discussion, the Paleozoic rocks can be subdivided into four sequences (fig. 3). A sequence is defined as the preserved sedimentary rock record bounded by regional unconformities (Sloss, 1963). In ascending order, the sequences are the Sauk, Tippecanoe, Kaskaskia, and Absaroka.

Sauk Sequence

The Sauk Sequence is represented by the Deadwood Formation. The part of the formation preserved in McHenry County is of Upper Cambrian age. The Deadwood is an onlap depositional sequence consisting primarily of a basal sandstone overlain by shale and carbonate and then by another sandstone. The upper part of the Deadwood Formation was probably removed by erosion in central North Dakota. The Deadwood Formation thickens southwestward over McHenry County from about 40 feet thick in the northeast to 250 feet in the southwest part of the county. Only one well, the same one that penetrated Precambrian rocks, has been drilled as deep as the Deadwood Formation in McHenry County.

Tippecanoe Sequence

The Williston Basin began to be a slightly negative area during deposition of the Tippecanoe Sequence. This sequence is the result of a transgressive event during which the seas invaded from the south and east, and the Williston Basin became part of a much more extensive epicontinental sea. The Tippecanoe Sequence is represented in McHenry County by rocks of Middle Ordovician to Silurian age. The initial deposits of the sequence were the clastics of the Winnipeg Group. These were followed by carbonates with minor amounts of evaporites of the

AGE	SEQUENCE	UNIT NAME	DESCRIPTION	THICKNESS (feet)
Holocene	Tejas	Oahe Formation	Sand, silt, and clay	0- 50
Pleistocene		Coleharbor Group	Till, sand, gravel, silt, and clay	0- 450
Tertiary	Zuni	Bullion Creek Formation	Sandstone and shale	0- 400
		Cannonball Formation	Marine sandstone and shale	0- 225
Cretaceous		Hell Creek Formation	Sandstone, shale, and lignite	0- 275
		Fox Hills Formation	Marine sandstone	0- 300
		Pierre Formation	Shale	1,000-1,300
		Niobrara Formation	Calcareous shale	125- 225
		Carlile Formation	Shale	140- 250
		Greenhorn Formation	Calcareous shale	100- 150
		Belle Fourche Formation	Shale	150- 200
		Mowry-Skull Creek Formations	Shale	175- 275
		Inyan Kara Formation	Sandstone and shale	175- 300
Jurassic		Swift Formation	Shale	150- 250
		Rierdon Formation	Shale	100- 150
		Piper Formation	Limestone	200- 400
Triassic	Absaroka	Spearfish Formation	Siltstone and sandstone	50- 300
Permian			(absent in McHenry County)	—
Pennsylvanian		Tyler Formation	Shale and limestone	0- 25
Mississippian	Kaskaskia	Big Snowy Group	Shale, sandstone, and limestone	0- 150
		Madison Group	Limestone, evaporites, and shale	700-1,600
		Bakken Formation	Siltstone and shale	0- 60
Devonian		Three Forks Formation	Shale, siltstone, and dolomite	0- 100
		Birdbear Formation	Limestone	60- 100
		Duperow Formation	Dolomite and limestone	275- 400
		Souris River Formation	Dolomite and limestone	150- 250
		Dawson Bay Formation	Dolomite and limestone	90- 180
		Prairie Formation	Halite	45- 60
		Winnipegosis Formation	Limestone and dolomite	100- 210
Silurian	Tippecanoe	Interlake Formation	Dolomite	200- 450
Ordovician		Stonewall Formation	Dolomite and limestone	70- 80
		Stony Mountain Formation	Dolomite, limestone, and shale	120- 150
		Red River Formation	Limestone	575- 635
		Winnipeg Group	Siltstone, sandstone, and shale	190- 220
Cambrian	Sauk	Deadwood Formation	Limestone, dolomite, shale, and sand	40- 250
Precambrian basement rocks			Igneous granitic rocks	—

Figure 3. Stratigraphic column for McHenry County.

Red River, Stony Mountain, Stonewall, and Interlake Formations.

In McHenry County, the Tippecanoe Sequence rocks range from about 1,200 feet thick in the east to about 1,500 feet in the west. Only four exploratory oil wells have been drilled as deep as the Silurian in McHenry County.

Kaskaskia Sequence

During deposition of the Kaskaskia Sequence, the Williston Basin was slightly more tectonically negative than during the previous two sequences. The initial deposits of the Kaskaskia Sequence represent a transgressive sea that spread over the area from the north and west during Devonian time.

Devonian formations that have been recognized in McHenry County include, in ascending order, the Winnipegosis (mainly carbonates), Prairie (mainly salt with some limestone and anhydrite), Dawson Bay (limestone and dolomitic limestone), Souris River (alternating limestone and thin argillaceous beds), Duperow (cyclical carbonates and shales), Birdbear (limestone), and Three Forks (shale, anhydrite, siltstone, and dolomite). The overlying Mississippian rocks were deposited mainly during normal marine conditions. They include rocks of the Bakken Formation (fine-grained clastics), the Madison Group (carbonates), and Big Snowy Group (shale, carbonates, and sandstones).

The Kaskaskia Sequence in McHenry County ranges from about 1,800 feet thick in the southeast to about 2,800 feet in the southwest; generally, the Kaskaskia rocks thicken westward. About 55 test holes have penetrated to the Madison or deeper in McHenry County.

Absaroka Sequence

McHenry County was flooded by a sea in early Pennsylvanian time and the Tyler Formation beds of shale and limestone were deposited over all or part of the county. If additional Pennsylvanian sedimentary rocks were deposited, they were later eroded away during a period of erosion that probably lasted throughout late Pennsylvanian and most of Permian time. Deposition of redbed clastics of the Spearfish Formation began in early Triassic time in McHenry County; no beds of Permian age have been identified in the county. The Spearfish redbeds cover the entire county, reaching a thickness of more than 200 feet in the western part.

Mesozoic and Tertiary Rocks

Mesozoic rocks (above the Spearfish) range in thickness from about 2,600 feet in northeastern McHenry County to about 3,700 feet in the southwest. All of these rocks are part of the Zuni

Sequence. Tertiary rocks are present over approximately the southwest third of McHenry County, reaching a maximum thickness of about 500 to 600 feet.

Mesozoic rocks of the Zuni Sequence in the Williston Basin consist mainly of clastic rocks that were deposited in widespread Jurassic and Cretaceous seas. Jurassic strata range from about 500 to 750 feet thick in McHenry County, east to west, and consist of evaporites, shale, and limestone of the Piper Formation, and fine-grained clastics of the Rierdon and Swift Formations. Cretaceous rocks include well-developed sandstone in the Inyan Kara Formation and a thin, poorly developed sandy facies in the Newcastle Formation. The rest of the Cretaceous rocks, below the Fox Hills Formation, are gray shales with some calcareous shales and thin bentonites. They include the Skull Creek, Mowry, Belle Fourche, Greenhorn, Carlile, Niobrara, and Pierre Formations. The Pierre Formation subcrops beneath the glacial deposits in two small areas in McHenry County, in valleys that were carved through the younger Cretaceous formations, probably by glacial meltwater streams.

The Fox Hills Formation conformably and gradationally overlies the Pierre Formation. It is a marine sandstone and shale sequence that subcrops beneath the glacial deposits throughout approximately the northeastern sixty percent of McHenry County (pl. 2). Over the remaining, southwest part of the county, the Fox Hills Formation is conformably overlain by the Hell Creek Formation. The Fox Hills Formation ranges from about 200 to 300 feet thick in the area where it is covered by Hell Creek sediment; over the remainder of the county, where its upper surface is eroded, the Fox Hills Formation averages about 150 to 200 feet thick.

The Hell Creek Formation, the youngest Cretaceous formation, conformably overlies the Fox Hills Formation in McHenry County. It is of continental origin and consists of interbedded gray, greenish-gray, and brown sandstone, mudstone, siltstone, carbonaceous shale, and thin lignite seams. The Hell Creek Formation directly underlies glacial sediment over its northeasternmost area (subcrop pattern on pl. 2) and it is conformably overlain by the Tertiary Cannonball Formation elsewhere. The Hell Creek Formation ranges from 200 to 275 feet thick where it is overlain by the Cannonball Formation, approximately the southwest third of McHenry County.

The Tertiary Cannonball Formation in McHenry County consists of marine sediments. It is largely olive black, carbonaceous and lignitic siltstone and shale, and micaceous, friable sandstone. The Cannonball Formation is about 225 feet thick in the southwestern corner of McHenry County, beneath the Bullion Creek Formation. It averages about 150 feet thick where it subcrops beneath the glacial sediment, except where it thins near its erosional edge.

The Bullion Creek Formation subcrops beneath the glacial sediment in southwesternmost McHenry County. The Bullion Creek Formation consists of silt and clay with varying amounts of sand, lignite, sandstone, and freshwater limestone. Where they are exposed, the Bullion Creek beds are generally buff to orange buff. In the subsurface, they are commonly yellowish brown, olive gray, and brownish black. The upper surface of the Bullion Creek is everywhere eroded and covered by glacial sediment. The formation reaches a thickness of about 400 feet in McHenry County.

Pleistocene Sediment

All the sediment related to glacial deposition in McHenry County, that is, all the materials that were deposited by the glacial ice as well as by flowing and ponded water associated with the ice, are collectively referred to as the Coleharbor Group. The Coleharbor Group has been subdivided into a large number of informal units and formally named formations by various geologists. Some of these units may be regionally correlatable, but others seem to have only local extent. I have generally avoided using the many formally named Coleharbor Group formations, referring instead to informal units.

Sediment of the Coleharbor Group is exposed throughout McHenry County. The Coleharbor Group sediment in McHenry County ranges up to over 400 feet thick in the southeast part of the county (pl. 3). Three main facies of the Coleharbor Group sediment are recognized in McHenry County: till; sand and gravel; and silt and clay.

Till Facies

The till of the Coleharbor Group found at and near the surface in McHenry County (map units Qcch, Qccu, Qcm, Qccr, Qcdg, Qct, Qcew, and Qcer) is typically a mixture of varying proportions of clay, silt, sand, pebbles, cobbles, and boulder-sized particles. The matrix, composed mostly of sand and silt-sized particles (54 percent sand, 43 percent silt, and 3 percent clay, based on sieve analyses of samples taken in the Drake area) is, in oxidized exposures, generally pale to medium yellowish brown when dry, or olive brown when moist. Fresh, unoxidized samples of till, taken during test-hole drilling, are medium to dark olive gray, tight, cohesive, and brittle. The depth of oxidation of the surface till in southern McHenry County ranges generally between 10 and 25 feet on the Glaciated Till Plain (fig. 1) averaging about 15 feet. It is oxidized to greater depths, up to 50 feet in places on the Missouri Coteau where relief is greater. The till found near the surface is commonly poorly indurated and it may be crudely jointed locally with gypsum crystals oriented parallel to the joint faces. It generally has no other recognizable structure, except for occasional dessication polygons, which can be seen in fresh road cuts.

The coarser grained materials in the till are generally angular to subrounded. Samples of near-surface till taken by Jenkinson (unpublished Master's thesis) in the Drake area had average coarse-grain compositions of 31 percent sandstone and 5 percent shale (total of 36 percent local rock types); 47 percent granitic, metamorphic, and basic igneous rock types; 15 percent carbonates; and 8 percent miscellaneous types.

In general, the igneous and metamorphic rock fragments in the till were ultimately derived from the Precambrian rocks of the Canadian Shield, to the east and northeast of McHenry County, and from the Tertiary sandstone formations of western North Dakota. Carbonate rock fragments were derived from Paleozoic rocks in Canada to the north and northeast of McHenry County, and the shale, sandstone, and lignite were derived from local bedrock formations. Many of the grains in the till were not transported directly from their outcrop areas to their present locations during a single advance of the glacier. An undetermined proportion of the sediment from each glacial advance was derived from older glacial sediment.

Sand and Gravel Facies

The sand and gravel facies consists largely of river channel sediment, with little or no overbank sediment. The deposits occur both as thin layers and lenses within the till and as thick, continuous sequences independent of the till. The sand and gravel facies of the Coleharbor Group covers the surface area of about 20 percent of McHenry County (areas of Qcrh, Qcrf, Qcrw, Qor, and the red lines, which represent ice-contact deposits). However, sand and gravel represents approximately 40 percent of the footage drilled during the study of the county. This higher figure is probably a more accurate measure of the total amount of fluvial deposits in the county. The discrepancy arises because much of the near-surface fluvial sediment is covered by a layer of wind-blown sand.

The sand and gravel facies is composed of subangular to subrounded, moderately well-sorted sand and pebble-sized detritus with small-scale and large-scale cross bedding and poorly sorted gravel with plane bedding. Locally, however, silt, cobble, and boulder beds are found. Minor folding and slumping occurs in sand and gravel pits in areas where the material was deposited in contact with stagnant glacial ice. In most good exposures of sand and gravel, beds with a small percentage of organic detritus occur in thicknesses ranging from less than an inch to several inches. This material is largely finely divided lignite, although some of it may be finely divided organic debris interbedded with fine sand. Ice-contact deposits, such as eskers and kames, are composed largely of fine to medium, well-sorted sand and gravel.

The sand and gravel facies of the Coleharbor Group has a mineralogic composition similar to that of the till. The mineralogy indicates that it is a combination of locally derived materials as well as materials that were ultimately derived from the north in Canada. The sand-size fraction is largely quartz and feldspars with minor amounts of shale and carbonates. The gravel-size fraction is commonly about half carbonates and the remainder granitics, shale, and western-derived siliceous rocks. Some of the gravel has a high percentage of shale. Near the surface, caliche ($CaCO_3$) coats the undersides of pebbles and cobbles. Generally, the sand is loose, but in some local occurrences, it is cemented with iron-oxide and forms a conglomerate. In areas where the sand and gravel is loose and uncemented, it is also highly permeable. The sand and gravel facies is generally the largest and most dependable source of high-quality groundwater in McHenry County.

The sand and gravel facies includes the deposits of both meltwater river and non-meltwater rivers; it is difficult to distinguish meltwater from non-meltwater fluvial deposits. Much of the material that has been referred to as "outwash" on previous maps was deposited by rivers consisting largely of runoff from precipitation rather than from meltwater. Even the "outwash" deposited by some meltwater rivers is not really outwash. For example, the sand and gravel deposited in the spillways in southeast McHenry County, southeast of the glacial Lake Souris plain, was transported by water flowing from the glacial lake. This water eroded pre-existing glacial sediment in the river cutbanks; it did not transport glacial outwash material.

Much of the sand found on and beneath the glacial Lake Souris plain (most of the water-deposited sand is masked beneath a layer of eolian sediment) is turbidity-current sediment that accumulated as fans at the mouths of streams flowing into Lake Souris. This material was deposited by continuous density currents originating from rivers flowing into the lake. The material on the upper parts of the density-current fans consists of well-sorted, fine to medium sand with flat bedding, small-scale cross bedding, and some large-scale cross bedding. This material is subject to wind erosion and is the source for the dunes and other eolian sediment in McHenry County.

Silt and Clay Facies

The silt and clay facies of the Coleharbor Group consists of materials that were deposited in lakes. In McHenry County, nearly all of the silt and clay was deposited as offshore turbidity-current sediment in glacial Lake Souris. Only very small amounts of lake sediment occur outside the area that was flooded by Lake Souris. The areas of silt and clay are designated mainly as Qcof and Qcon, with small areas of Qcsl, Qcst, and Qos on the geologic map (pl. 1). Even though the areas of silt and clay are quite limited in aerial extent in McHenry County (that is to say, surface exposures are not extensive), a fairly extensive deposit of offshore lake sediment occurs in the northeastern part of the county (fig. 4). Throughout much of this area, however, the lake sediment is masked by a covering of eolian sand.

The silt and clay that was deposited in glacial Lake Souris ranges up to about 115 feet thick, and it is nearly 100 feet thick in a number of places. The variation in thickness is probably mainly the result of relief on the till surface on which the lake sediment was deposited. Throughout the area that was flooded by glacial Lake Souris, the clay and silt facies sediment averages about 35 feet thick.

Generally, where it is exposed, the silt and clay consists of a yellowish-brown material. It is most often characterized in sample descriptions as a silty clay, but samples I examined were almost entirely silt with only thin laminae of clay or carbonaceous clay. Detrital lignite is commonly interbedded in the material. Unoxidized exposures are dark olive gray.

GEOMORPHOLOGY

General Description

The modern landscape in McHenry County is the surface that was formed by the Wisconsinan glacier that covered the area and by the glacial Lake Souris, which flooded approximately the northern half of the county when the glacier melted. Considerable modification of the lake plain surface by wind action after the lake drained resulted in large dunes in some places.

Most of the landforms in southern and western McHenry County formed due to the collapse of glacial sediment when the glacial ice melted about 12,000 years ago. The melting of the stagnant glacial ice on the Missouri Coteau in extreme southwestern McHenry County resulted in the most rugged glacial topography in the county. The glacial ice on the Missouri Coteau probably melted somewhat later than did the ice in the rest of the county. Over most of the till plain in southern and western McHenry County the relief is low except in places where the glacier shoved blocks of material into prominent hills.

Surface elevations rise about 600 feet across the county, from below 1,500 feet in the northeast to over 2,100 feet in the southwest, with the sharpest rise occurring in the southwest along the Missouri Escarpment, where elevations rise from about 1,800 feet to over 2,100 feet in a distance of about 4 miles. The

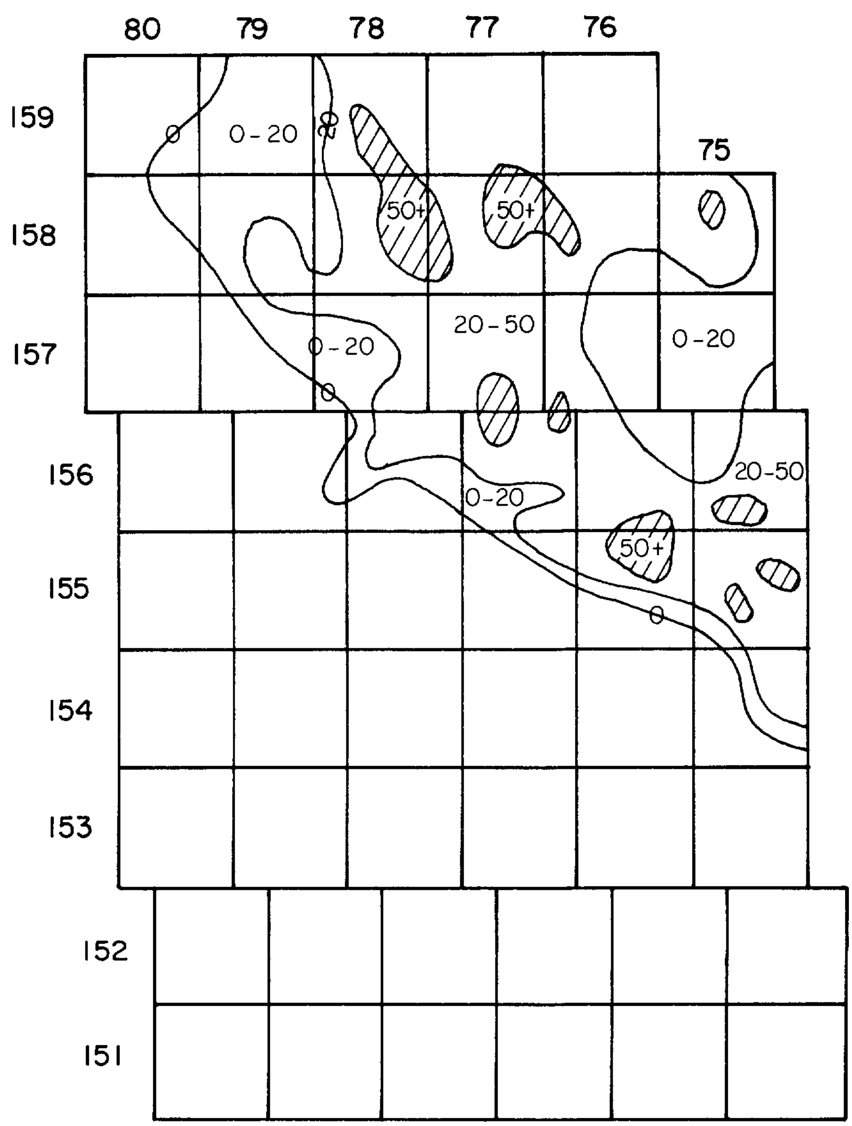


Figure 4. Isopach map of offshore clay and silt deposited in glacial Lake Souris.

rise in surface elevations is largely the result of a comparable rise on the bedrock surface beneath the glacial sediment.

The McHenry County till plain, which includes approximately the southern half of the county (fig. 1) is notable in that it is spectacularly fluted with low, drumlin-like ridges, many of which are several miles long and almost perfectly straight.

The glacial Lake Souris plain, which covers most of the northern half of McHenry County, is flat except in the areas of dunes. Even in areas where dunes are not present, the lake plain, in most places, is covered by a nearly continuous veneer of eolian silt and fine sand.

The landforms of the McHenry County till plain have been worn by wave action along the shore of glacial Lake Souris and by running water, which has washed the surface in some places, leaving a lag of boulders, and depositing a veneer of gravel and sand in other places. The valley of the Souris River has been carved about 150 feet deep where it crosses the till plain. It is generally less than 50 feet deep over the glacial Lake Souris plain.

Glacial Landforms

Collapsed Glacial Topography

Hilly and hummocky glacial topography results from the lateral movement of supraglacial sediment as it subsides (collapses, is let down, or slides to lower elevations in the form of mudflows) when the underlying ice melts out from under it (Clayton, 1967; Clayton and Moran, 1974; Clayton, Moran, and Bluemle, 1980). Although this is the generally accepted explanation for the origin of hummocky glacial topography, two alternatives have been suggested. Stalker (1960) suggested that hummocks resulted from the squeezing of subglacial sediment into irregularities in the base of a stagnant glacier. However, hummocks composed of glacial sediment are essentially identical to hummocks composed of collapsed supraglacial fluvial and lacustrine sediment that lacks evidence of ever having been under a glacier. Bik (1967) suggested that hummocks resulted from the movement of sediment during the growth and decay of permafrost; he considered them to be relict pingos. However, in North Dakota, hummocks were generally formed at a time when paleoecologic evidence indicates a climate too warm for permafrost, and hummocks are generally absent in North Dakota in areas known to have had permafrost (Clayton, Moran, and Bluemle, 1980).

On the geologic map of McHenry County (pl. 1), the collapsed glacial topography (Qcch, Qccr, Qccu) is subdivided on the basis of its most conspicuous variables: slope angles, overall relief, presence or absence of ring-shaped hummocks, and presence or absence of transverse ridges.

The most widespread glacial landform in McHenry County is undulating collapsed glacial topography (Qccu on pl. 1) (fig. 5). It has low relief (generally less than 10 feet locally), poorly integrated drainage, and maximum slope angles of less than 4°. Closely associated with this glacial landform in McHenry County is an abundance of straight ridges, all of which trend between N50° W and N55° W. They were molded at the base of the last moving glacier, which was moving in a southeasterly direction (see the discussion of subglacially molded surface, page 19).

The undulating collapsed moraine also has abundant washboard ridges in some places (pl. 1). Areas of washboard ridges consist of series of low transverse ridges and shallow trenches spaced about 650 feet apart and with local relief of 5 to 10 feet. They are best seen on airphotos. The ridges and trenches are gently curved, with a radius of curvature of 15 to 20 miles, concave upglacier (to the northwest). The ridges may have formed as the result of greater concentrations of glacial sediment along periodically spaced transverse shearing zones near the margin of the glacier.

Southwest of the area of undulating collapsed glacial topography is an area of rolling collapsed glacial topography (Qccr on pl. 1). This landform has somewhat better integrated drainage than the undulating topography and local relief of less than 50 feet in most places. In McHenry County, the rolling collapsed topography has a regional northeasterly slope, away from the Missouri Escarpment.

A small area of about 10 square miles in southwesternmost McHenry County (T151N, Rs79-80W) is classified as hilly collapsed glacial topography (Qcch on pl. 1; fig. 6). This landform occurs on the Missouri Coteau and is the result of large-scale glacial stagnation. Most of the landforms in this area are ultimately the direct result of mudflows. As the stagnant glacier melted, topography on the surface of the ice was continually inverted. When sinkholes in the stagnant glacier finally melted through to the solid ground beneath, circular holes formed in the glacier. Material flowing down the sides of these holes completely filled many of the holes, resulting in hills of material occupying the positions of the former sinkholes when all the ice finally melted. If the amount of material flowing into a hole was not enough to completely fill it, the material formed a doughnut-shaped ridge at the base of the sides of the hole; ridges such as these are commonly called "circular disintegration ridges" or "doughnuts." If, in the final stages of topographic inversion, thick deposits of material in the bottom of sinkholes caused them to invert into ice-cored cones, the material may have flowed down the sides of the cones, producing, when all the ice had melted, doughnut-shaped ridges, also called circular disintegration ridges. Any ridges formed by material moving down ice slopes and collecting at the base of slopes are called

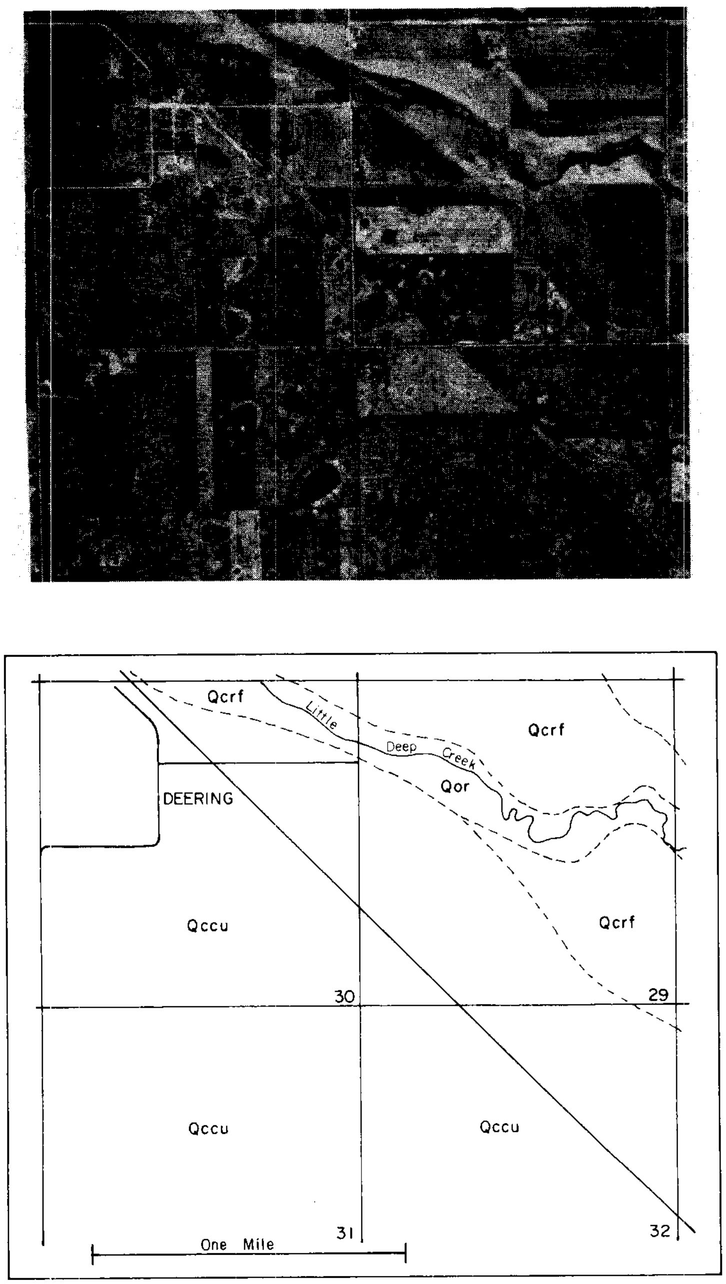
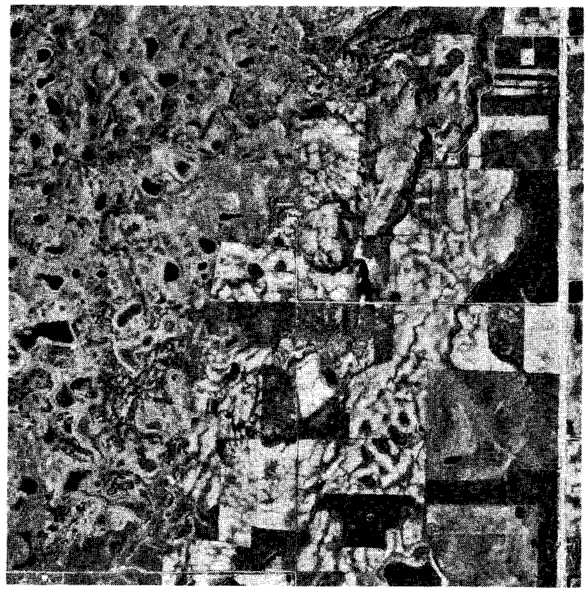


Figure 5. Typical undulating collapsed glacial sediment (Qccu) near Deering in western McHenry County (secs 29, 30, 31, and 32, T157N, R80W).



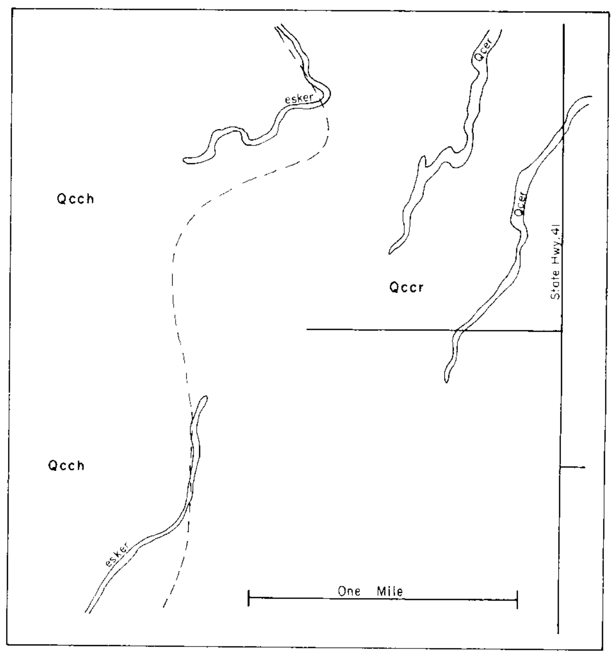


Figure 6. Strongly rolling collapsed glacial sediment (Qcch) and rolling glacial sediment (Qccr) located in the southwest corner of McHenry County (secs 17, 18, 19, and 20, T151N, R80W). Two eskers are shown. Two small areas of stream-eroded glacial sediment are shown.

"disintegration ridges." The ridges generally form random patterns and they may be any shape, from circular to straight, depending on the shape of the former ice slope and the fluid content of the sediment as it slid into place.

Subglacially Molded Surface

As noted earlier, the topography in south-central McHenry County is characterized by an abundance of longitudinal shear marks. These spectacularly developed shear marks are abundant in the area between Verendrye and Balfour (figs. 7, 8, 9), in the area of subglacially molded surface (Qcm on pl. 1). The shear marks are largely the result of glacial erosion. In some places, truncation of cross bedding in sand by a veneer of glacial sediment suggests that the sand, which forms the core of some of the ridges, is a remnant of a once more extensive area of river flood-plain deposits. Large shear marks are most generally composed of highly permeable and slightly compressible sediment, probably because this favored dissipation of excess pore pressure and the increase of intergranular pressure (Clayton and Moran, 1974). This provided a large amount of force for abrasion, as on tectonic thrust planes (glacial sediment in the abrasion zone is analogous to fault gouge).

In every longitudinal shear mark observed in McHenry County, the glacial sediment of the last advance is so thin that it contributes little or nothing to the volume of the landforms. Where the surface layer is thicker, it masks the shear marks; landforms composed of let-down glacial sediment are draped over the shear marks. Where the surface layer of glacial sediment is thicker than the height of the shear marks, they are completely buried and can be identified only by subsurface stratigraphic studies.

Ice-Thrust Masses

Ice thrusting near the terminus of the active glacier in McHenry County (Qct on pl. 1) and in many other parts of North Dakota, resulted in compressional folds and thrusts (fig. 10) of the subglacial sediment (Bluemle, 1970; Clayton, Moran, and Bluemle, 1980; Moran and others, 1980). Vertical displacement was typically tens of feet, and the individual folds or thrust masses are commonly about 600 feet across.

Ice thrusting was intense in the area immediately south of McHenry County, especially in Sheridan County (Bluemle, 1981). Large-scale thrusting that occurred in McLean County resulted in the formation of Dogden Butte. In McHenry County, the largest ice-thrust mass is the area known as the Henderson Hills (secs 2, 3, and 11, T155N, R79W; secs 34 and 35, T155N, R79W) where relief reaches 100 feet locally. The surface over the Henderson Hills is mainly till, but gravel is exposed along the sides of the hills in several places. Another area of ice-

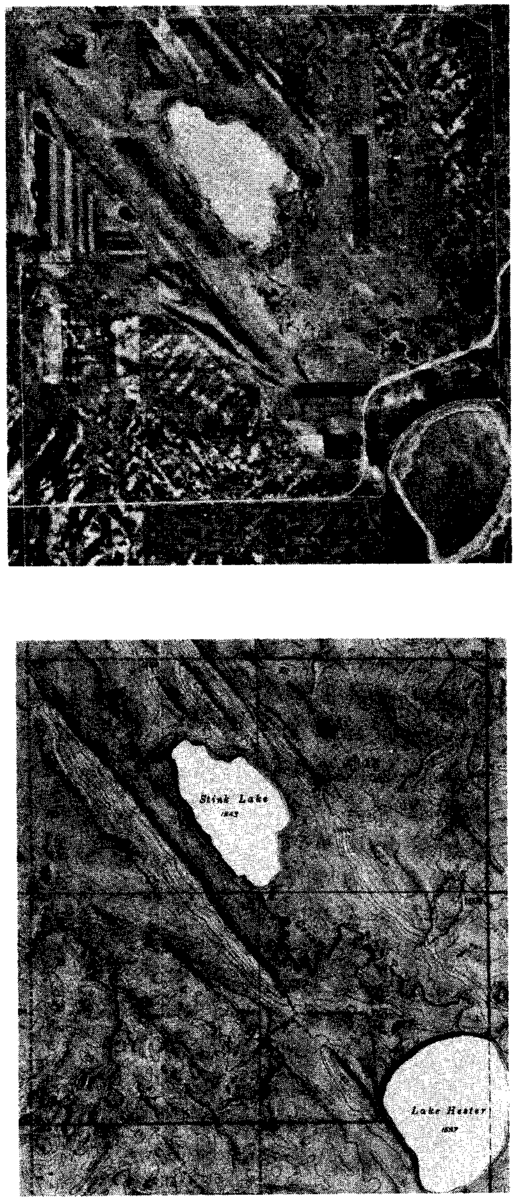


Figure 7. Fluted area between Velva and Verendrye (secs 13, 14, 23, and 24, T153N, R79W). This view also shows the point where the early Souris River (pre-Lake Souris) spilled out of its valley southeastward.

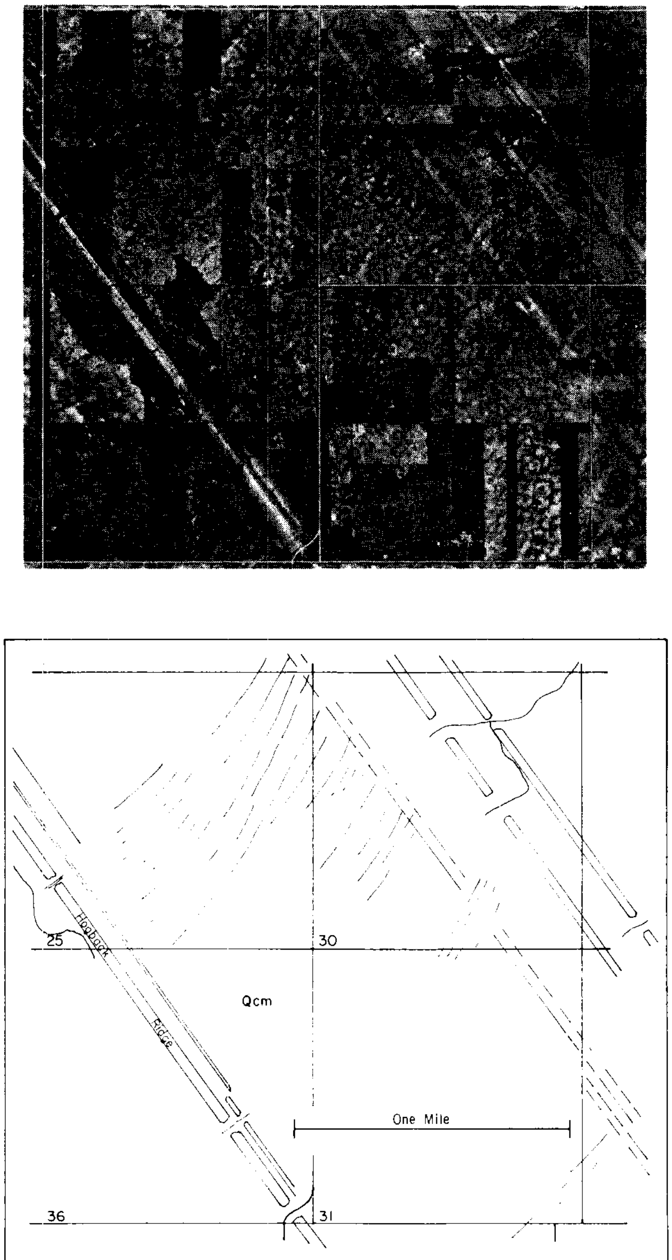


Figure 8. Hogback Ridge and nearby longitudinal shear markings about four miles northeast of Bergen (secs 30 and 31, T153N, R77W, and secs 25 and 36, T153N, R78W). Washboard ridges cross or abut against some of the lower shear ridges, and the ridges are also breached by some small drainages.

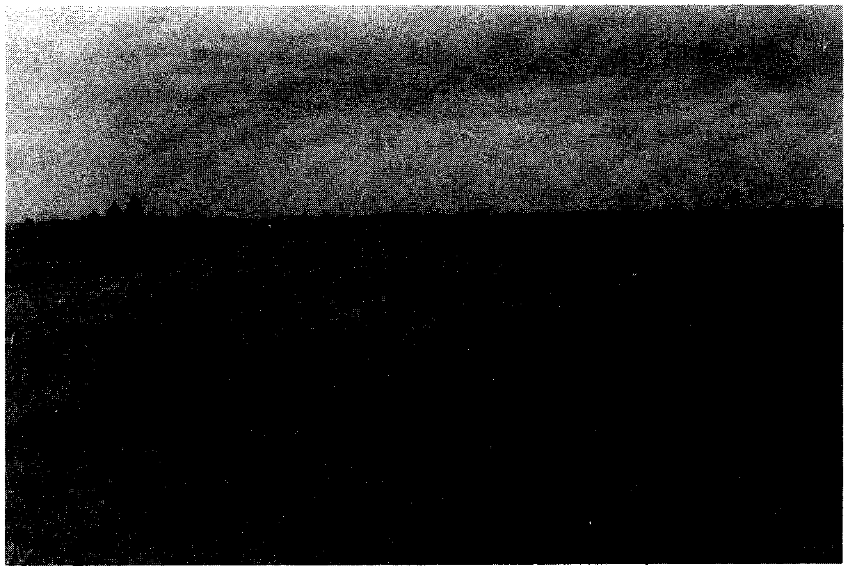


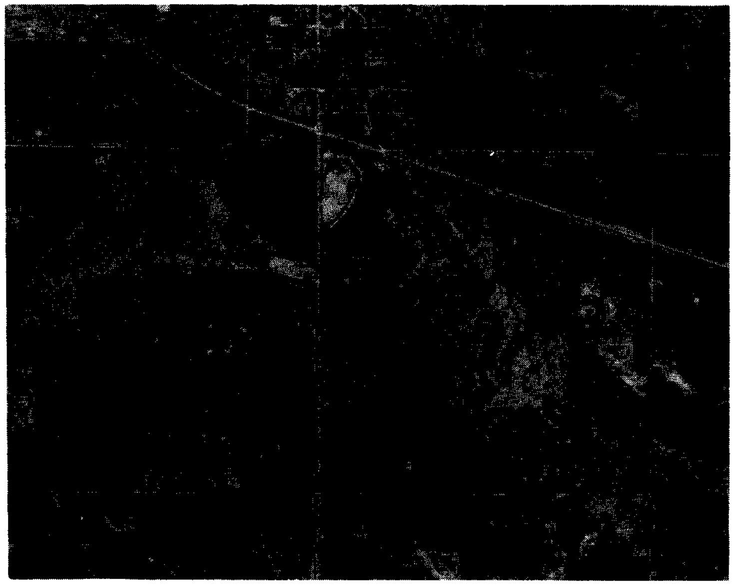
Figure 9. Crest of Hogback Ridge. View to the southeast, about a mile from Verendrye (southeast corner of sec 4, T153N, R78W). The spectacular linear aspect of the ridge, so striking in air views (see figs. 7 and 8), is not apparent from the ground.

thrust topography northeast of Velva (sec 32, T154N, R80W) is also largely till overlying sand. The ice-thrust mass here stands about 125 feet above the adjacent area of undulating collapsed glacial topography.

Buffalo Lodge Butte (secs 24 and 25, T156N, R79W) is another ice-thrust mass that consists mainly of sand and gravel overlain by till. Two distinct layers of till are exposed overlying the gravel near the top of the butte, which was apparently thrust from the northwest from a depression now occupied by a small lake. Buffalo Lodge Lake, east of the butte, appears to be unrelated to the thrusting episode. It probably occupies a depression that corresponds to a buried valley.

The "classic" source depression/ice-thrust hill combination is found at Anamoose, in southeasternmost McHenry County (secs 26 and 27, T151N, R75W). The depression here is almost the same size and shape as the hill (fig. 11). The fact that the depression, which is now occupied by Steele Lake, was the source for the hill is obvious. The ice-thrust hill at Anamoose is about a hundred feet high. An esker that begins at the hill and extends southeastward from there, probably formed when excess pore-water pressure escaped during the thrusting episode.

Figure 10. Two photos of ice-thrust sand overlying till at the McHenry-Sheridan county line. Exposure is located in the southwest corner of sec 31, T151N, R78W.



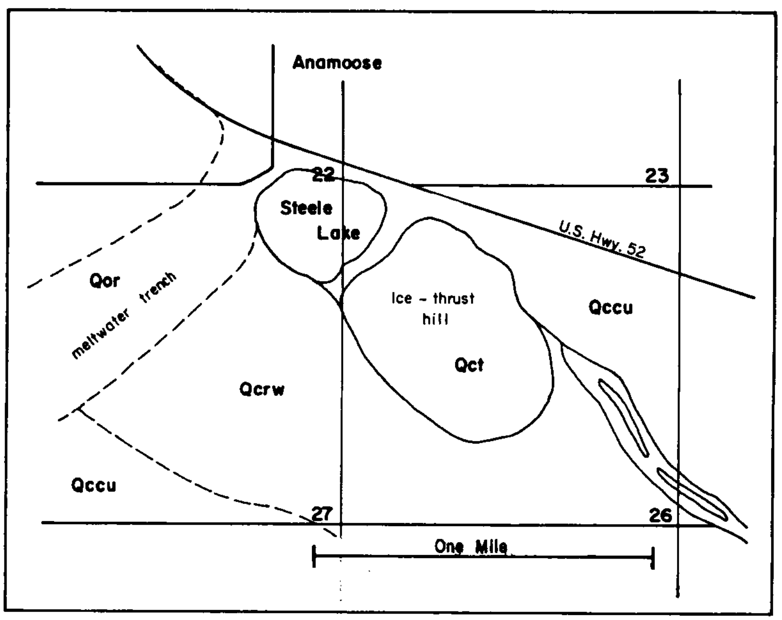


Figure 11. Ice-thrust mass (Qct) and adjacent depression occupied by Steele Lake in southeastern McHenry County at Anamoose (secs 22, 23, 26, and 27, T151N, R75W).

Relict Topography

In some places, thin glacial sediment is draped over the earlier glacial or nonglacial topography, only slightly modifying the older surface that existed before the last glacial advance over the area. In some places in McHenry County, outcrops show that the glacial sediment of the last advance is only 1 or 2 feet thick.

Glacial sediment draped over pre-existing glacial topography (Qcdg on pl. 1) has been mapped in areas where pre-existing collapsed glacial topography, collapsed fluvial topography, or glacial thrust masses are interpreted to have been only slightly modified during the last glacial advance.

The most extensive area of relict topography mapped is in east-central McHenry County, extending southeastward from the feature known locally as "Bald Butte." It is probable that this area is mostly an overridden glacial thrust mass. The thrusting appears to have been from the northeast and the area was subsequently overridden by ice flowing from the northwest. The latest, southeast-moving glacier also resulted in some streamlining of the topography, both in the Bald Butte area and in other areas of relict topography.

Water-Worn Glacial Topography

In a few places, the till surface in McHenry County has been washed by running water and by wave action along the shore of glacial Lake Souris. Steep, eroded slopes of till along the Souris River Valley (Qcer on pl. 1) in the Velva area are quite bouldery. These boulders were left behind as a lag deposit when the running water that washed the surface removed the finer materials that had been part of the glacial sediment. In northwestern McHenry County, wave action along the shore of glacial Lake Souris planed off the surface, resulting in a nearly flat, bouldery surface (Qcew on pl. 1).

Lacustrine Landforms

Offshore Lake Deposits

Most of the northern half of McHenry County was flooded by glacial Lake Souris (fig. 12), but throughout most of that area the surface has been modified by wind action, resulting in a layer of eolian sediment on top of the lake deposits. Scattered patches of offshore lake sediment are found exposed at the surface in northern McHenry County (Qcof on pl. 1).

Glacial Lake Souris seems to have existed at two levels in McHenry County (fig. 13). The upper, older level is more restricted and probably formed as several ice-walled lakes when much of the lake basin was still filled with ice. The lakes flooded elevations above about 1,485 feet, and up to 30 feet of bedded silt was deposited in these lakes (that is, the modern

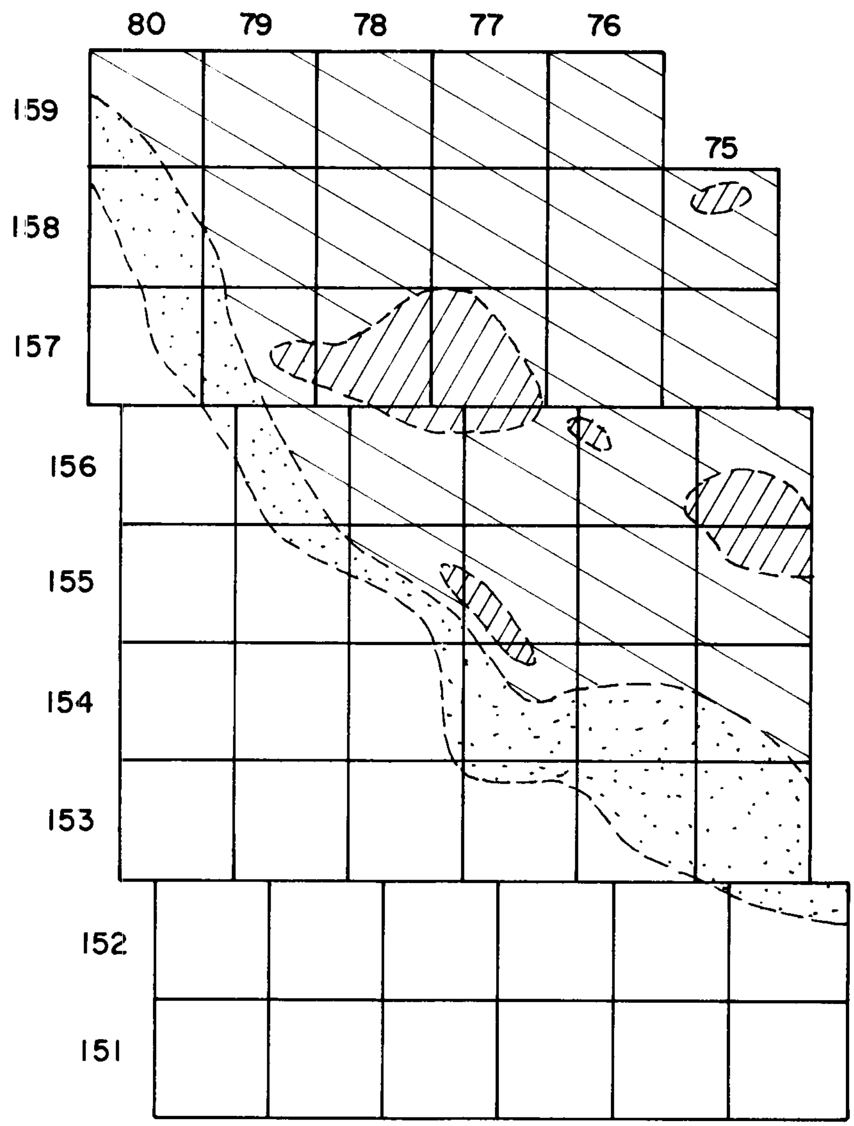


Figure 12. Map of McHenry County showing the area that was flooded by glacial Lake Souris. Broad shaded area is largely offshore, turbidity-current sediment. Stippled area is largely nearshore deposits. Narrow lined areas represent probable ice-walled and supraglacial deposits. These areas were flooded earlier and at a slightly higher elevation than the remainder of the glacial Lake Souris plain. Much of the lake plain is obscured by a layer of eolian sediment.

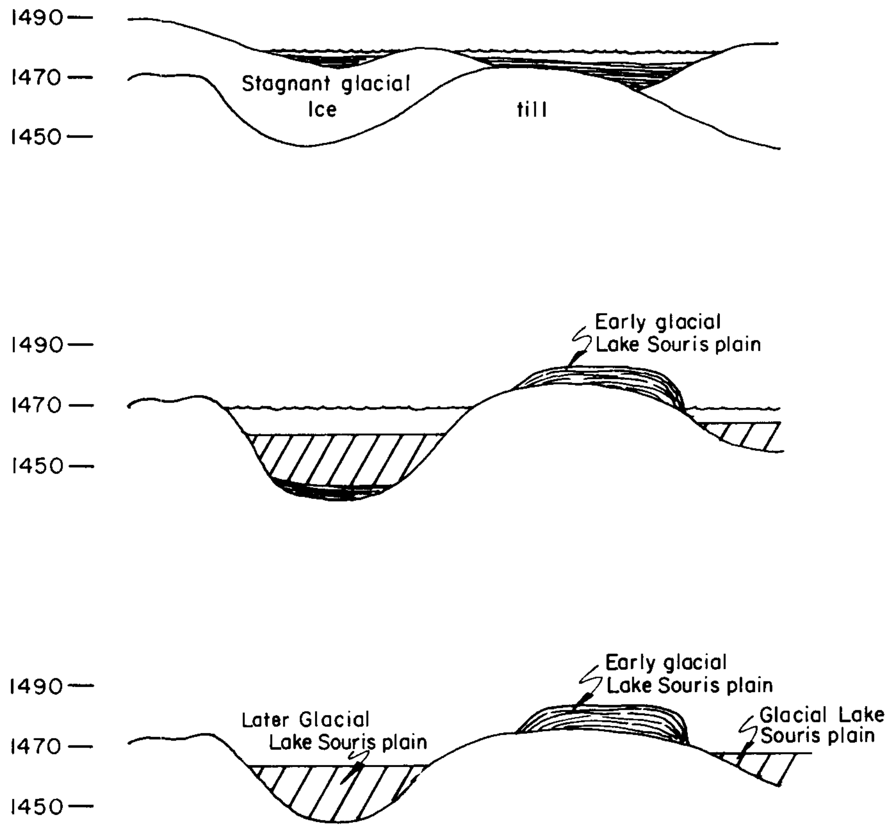


Figure 13. Schematic cross sections showing the development of glacial Lake Souris in McHenry County. As the glacier melted, ponding took place in depressions and holes in the ice, forming a discontinuous proto-glacial Lake Souris (A, above). The layers of lake sediment that accumulated in this lake/lakes are found at elevations above about 1,485 feet and they are generally less than 30 feet thick (shaded layers). When the remainder of the ice melted (B, above), glacial Lake Souris expanded, flooding the entire basin. Lake sediment (hatched layers) up to 125 feet thick accumulated in the larger lake at elevations below about 1,475 feet.

surface is at 1,485 feet and 30 feet of silt lies below that elevation, above till, which is at 1455 feet). Some of the lakes may have been supraglacial as well as ice walled.

Later, when most of the ice had melted, the lakes expanded, flooding the basin at elevations generally below 1,475 feet. Over 50 feet of lake sediment was deposited in many places in this lower, more extensive lake, and up to 125 feet of bedded silt was deposited in some places. The elevations of the upper surface of this lower unit of lake sediment is fairly level, but the lower surface is irregular and coincides with the surface on the underlying till unit. The lake sediment filled in the depressions, resulting in the flat lake plain that exists today.

The sediments deposited in glacial Lake Souris are largely silt and well-sorted very fine to medium sand with flat bedding. Most of the deposits are probably turbidity-current sediment. The sandy silt was later easily blown by the wind and this resulted in extensive blowouts, large dunes, and a fairly continuous layer of wind-blown silt in areas where dunes did not develop.

Nearshore Lake Deposits

Large amounts of sand and gravel are found along the former shoreline of glacial Lake Souris. Broad deltas (Qcsl on pl. 1) were built into the lake by the Souris River and by other streams flowing into the lake.

Throughout much of northern McHenry County, broad transitional areas of nearshore to offshore sand and silt (Qcon on pl. 1) occur. These deposits grade into the nearshore sand and they are generally obscured on the offshore side by an eolian mantle.

In some places it was possible to identify nearshore sand overlying glacial till (Qcst on pl. 1). This sand is generally less than 3 feet thick and till is exposed in many places where the sand is not present.

It was not possible to identify specific shoreline deposits that may have formed during the early flooding episode, but possible beach deposits were noted in several places at elevations ranging from about 1,530 feet to approximately 1,540 feet (Karlsruhe area, south of the Souris River). These beach(?) deposits may relate to the upper lake level and, if they do, they would suggest that the lake (or lakes) might have been as much as 85 feet deep (1540-1455=85) before they were filled in with sediment.

Probable shore line sediments are most common at about 1,510 to 1,515 feet. These materials were likely deposited along the shore of the lower lake. They suggest that the lower lake was well over 100 feet deep in places before it became filled in with sediment.

Modern Ponds and Sloughs

McHenry County has numerous small sloughs in the area of collapsed glacial topography (Qos on pl. 1). The density of sloughs is greatest in the more hilly areas, such as the extreme southwestern corner of the county. Most of the sloughs found in areas of collapsed glacial topography occur in potholes, depressions left when buried blocks of stagnant glacial ice melted from the glacial sediment.

Somewhat larger sloughs are found in several places over the area that was flooded by glacial Lake Souris. Many of the depressions in which these sloughs occur are blowouts, formed during a time when the water table was lower than it is today. Others probably formed in the same way as the depressions found in areas of glacial topography, by the melting of buried blocks of stagnant glacial ice.

Ponds and lakes in the depressions on the lake plain are usually the same level as the groundwater table. As a result of the smaller amount of evaporation at the surface of the underground part of the groundwater reservoir, these lakes and sloughs have fresh water and a stable water level. Fish, pelicans, ducks, and gulls frequently occupy these gravel-bottomed lakes, and trees and shrubs grow along their shores. In contrast, lakes floored entirely by impermeable till or lake clay usually have a high salt concentration and a rapidly fluctuating water level, so many of these are intermittent. Fewer fish and water birds live in these lakes.

In some places, deposits of peat and decomposed peat ("muck") are found in sloughs. This material is generally less than three feet thick. Sediment in the sloughs has been derived largely from adjacent hillslopes. It consists of dark, clayey material alternating with layers of lighter colored, more silty beds.

Fluvial Landforms

Landforms resulting from the action of running water include deposits of both meltwater rivers and non-meltwater rivers. They were left undifferentiated because no consistent way of distinguishing them is known. Much of the material called "outwash" on previous maps was deposited by rivers consisting largely of runoff from precipitation rather than from meltwater. For example, the youngest "collapsed outwash" of the Missouri Coteau was deposited thousands of years after the glacier stagnated, when less than a tenth of the runoff was derived from melting ice (Clayton, 1967, p. 36). Even the "outwash" deposited by some meltwater rivers is not really outwash. For example, much of the sand and gravel in southern McHenry County (Qcrf) was deposited by floods of water flowing from glacial Lake Regina to the northwest of the study area. Much of the sand and gravel along the edge of glacial Lake Souris in western McHenry County was delivered to the lake by small streams flowing into the lake. This material is, in a sense, "deltaic" sediment.

In McHenry County, the fluvial landforms include several meltwater trenches; glacial river flood plains and stream terraces including both flat and hilly (collapsed) surfaces; and various ice-contact deposits including eskers and kames.

Meltwater Trenches

The best defined meltwater trench in McHenry County is the valley of the Souris River upstream from the point at which it enters the glacial Lake Souris plain. The meltwater trench is about a mile wide and 100 to 150 feet deep from the McHenry-Ward County line, through T153N, Rs79-80W. Downstream from the point at which the meltwater trench enters the glacial Lake Souris plain, in T154N, R78W, it is broader and more shallow (fig. 14).

Extensive gravel terraces occur along the sides of the Souris River meltwater trench downstream from Velva for a distance of about 8 miles. These terraces are graded to two cutoff meltwater trenches that trend southeastward, the first emanating at Velva (secs 25 and 26, T153N, R80W), and the second about 5 miles northeast (downstream) (secs 9 and 10, T153N, R79W). These two cutoff valleys join near Bergen, forming the Wintering River Flats (fig. 15).

The southern part of McHenry County is crossed by several small trenches that apparently carried overflow from glacial Lake Souris at various times. Some of these trenches contain gravel deposits, but others are merely scoured valleys.

An intricate system of numerous meltwater trenches enters the glacial Lake Souris plain in northwestern McHenry County. These valleys are mainly less than 0.2 mile wide at the point at which they enter the lake plain, where they broaden to fan-like features. Where they cross the till plain, the small valleys are from 10 to 30 feet deep.

The only noteworthy meltwater trench on the glacial Lake Souris plain is the Souris River Valley. It is from one to three miles wide and generally less than 25 feet deep. Large amounts of fine- to medium-grained sand are found along the meltwater valley in the Towner area, but coarser gravel deposits are absent.

River Flood Plains and Terraces

The sediment of proglacial rivers in McHenry County occurs as flat, fluvial plains (Qcrf on pl. 1); as valley side terraces (also Qcrf--mainly found in the area between Velva and Verendrye); or as hummocky topography (Qcrh) almost identical

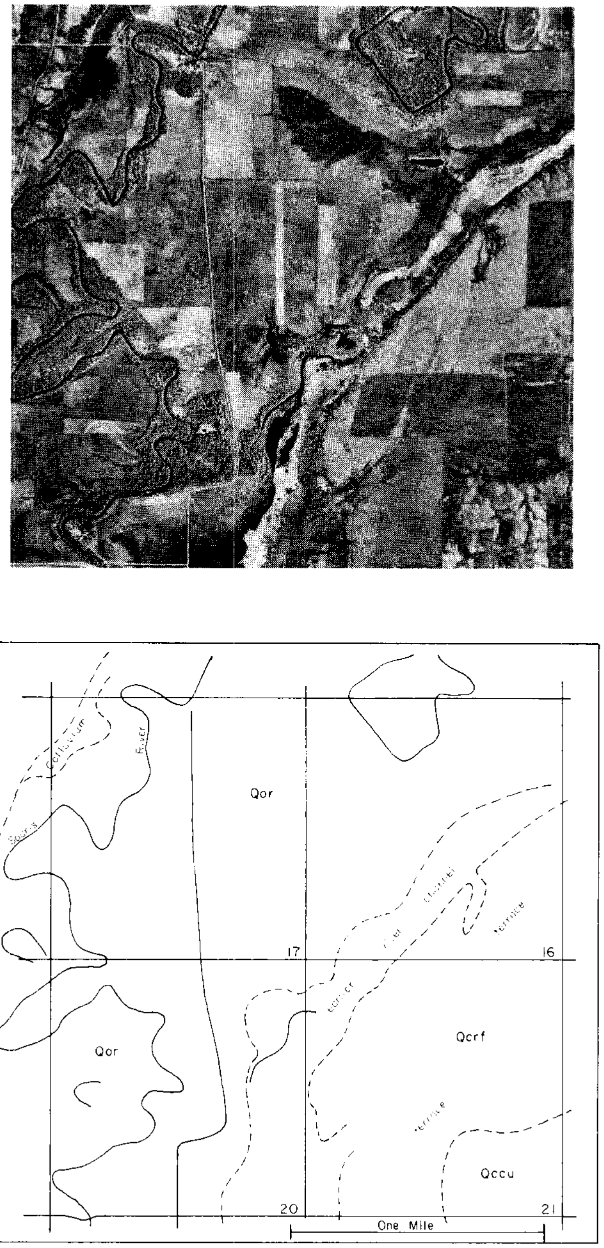


Figure 14. Souris River Valley north of Verendrye (secs 16, 17, 20, and 21, T154N, R78W). The Souris River meltwater trench is broad and shallow where it crosses the lake plain. The meandering pattern of the Souris River today is in sharp contrast to the route the river took during an earlier time of greater precipitation (route shown by "earlier river channel," above).

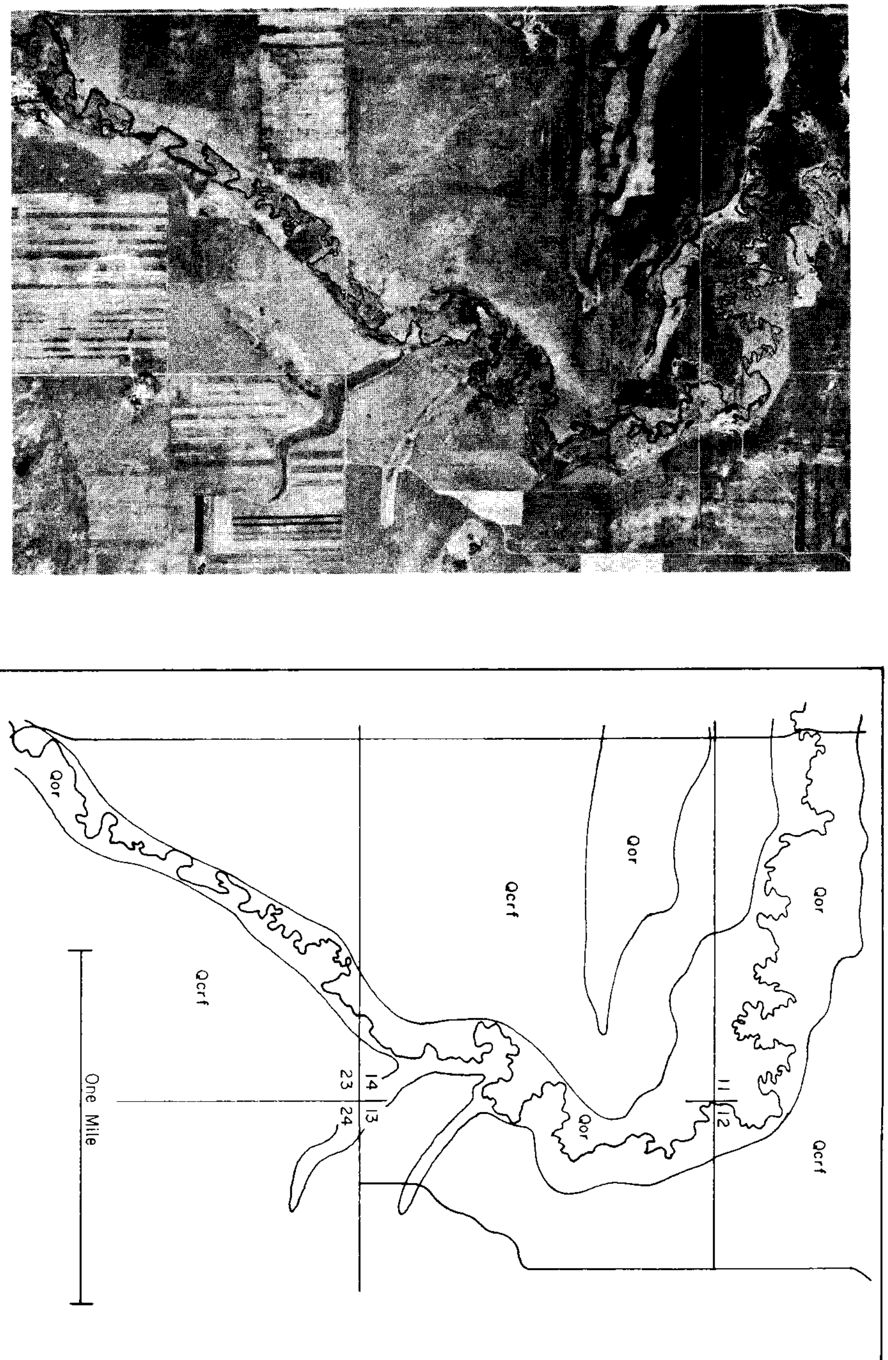


Figure 15. Wintering River about five miles northeast of Karlsruhe (secs 11, 12, 13, 14, 23, and 24, T154N, R77W). The river has an extremely tortuous route across this flat area of the Souris lake plain. Most of the surface sediment in this area is flat stream sediment.

to the landscape typical of collapsed glacial topography (Qcch or Qccu).

Most of the fluvial materials in McHenry County lie beneath a flat to gently undulating surface and are themselves relatively flat lying. The most extensive areas of such fluvial deposits are found along the western margin of glacial Lake Souris and in the southern part of the county, in association with the melt-water trenches already described. Considerable gravel deposits are found in these areas. Only small areas of undulating to rolling fluvial deposits (Qcrh) are found in McHenry County. Most of these occur in the southern part of the area (pl. 1).

In southeastern McHenry County, several areas of water-worn glacial sediment are found. These are overlain by a veneer (3 feet or less) of fluvial material (Qcrw on pl. 1). In places, the till surface is mainly bare, but bouldery with occasional patches of gravel or sand.

Modern fluvial overbank material (Qor on pl. 1) occurs on the Souris River flood plain and on some of the smaller stream flood plains in southern McHenry County. The modern river flood plains are flat and commonly underlain by up to 25 feet of flat-bedded, organic silt and clay (clay is especially prevalent in northern McHenry County in the glacial Lake Souris plain area).

Eskers and Kames

Numerous small eskers are found in southeastern McHenry County, but only a few of the larger ones are shown on the geologic map (red lines on pl. 1). The eskers are essentially the same as areas of hummocky flood-plain material (Qcrh), but they occur as long, narrow ridges, easily differentiated ice-contact deposits (fig. 16). Most of the eskers were identified by airphoto interpretation. The eskers are composed of gravel, sand, and some till. The mixture is poorly sorted and rather "dirty" with a ratio of silt and clay to gravel and sand of about 3:1. The shale content is high in some of the eskers. Some of the gravel is used locally for road material, but, in general, the quality of the fluvial sediment in the eskers is too poor for commercial use.

A few large kame-like features occur in McHenry County. Examples are Mike's Peak (secs 26 and 27, T155N, R79W) and the Henderson Hills (sec 3, T154N, R79W; secs 34 and 35, T155N, R79W). Both of these ice-contact features are about 100 feet high and composed of gravel and coarse sand. The Henderson Hills are about a mile and a half long and Mike's Peak is about a mile long. Large masses of till several tens of feet in length were seen in exposures on Mike's Peak. A similar ice-contact feature is Black Butte (sec 1, T153N, R81W) about a half mile west of the McHenry County line in Ward County.

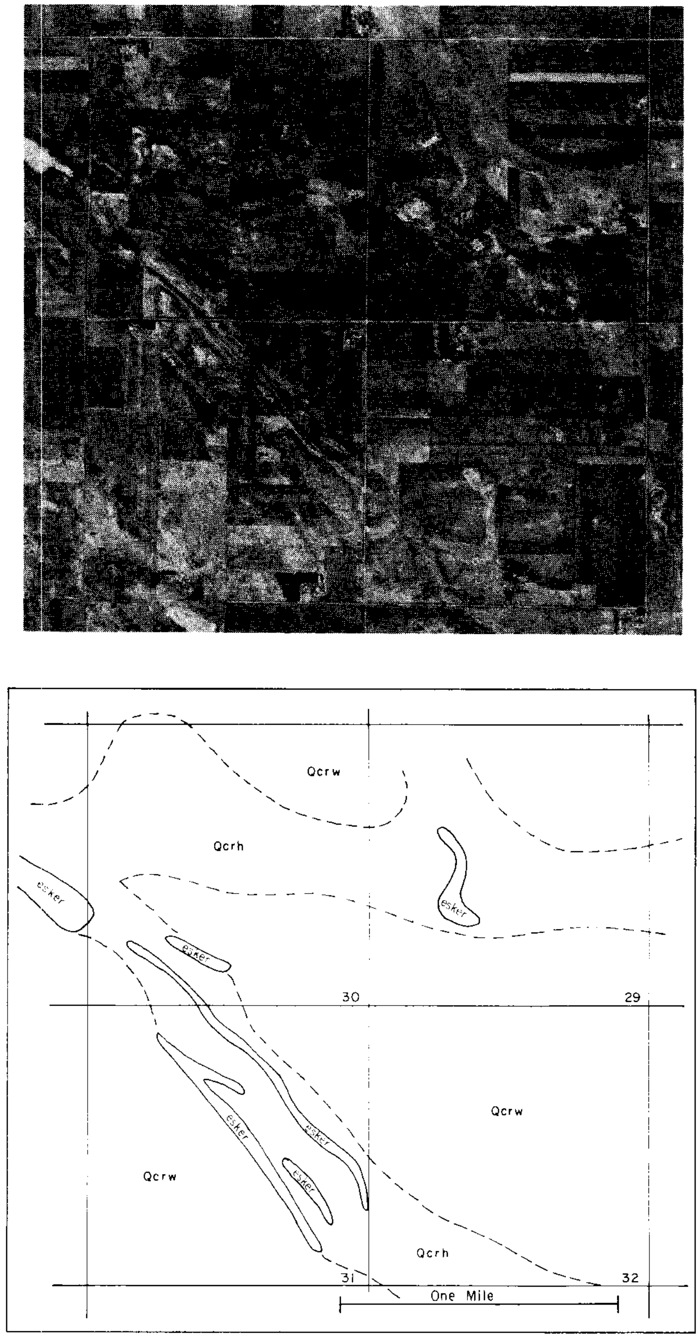


Figure 16. Several eskers about four miles southeast of Drake in southeastern McHenry County (secs 29, 30, 31, and 32, T151N, R75W).

Eolian Landforms

Approximately three-quarters of the glacial Lake Souris surface in McHenry County is mantled by a layer of eolian sediment (figs. 17 and 18). The McHenry County wind-blown silt and sand has been derived largely from well-sorted sand that accumulated in glacial Lake Souris in the upper parts of density-current fans. Prominent dunes reach heights greater than 65 feet in places (Qod on pl. 1). In fact, the McHenry County dunes are among the most spectacular in North Dakota. Over much of the lake plain, in places where dunes are absent, a veneer of wind-blown sand is found (Qou). In these areas, and on the dunes as well, a strong northwest-southeast "grain" is apparent on airphotos.

Colluvial Landforms

At the base of certain steep slopes, such as the Missouri Escarpment in the southwestern corner of McHenry County (secs 31, 32, 33, T151N, R79W), accumulations of colluvial material are found. These unsorted mudflow sediments are bouldery to sandy and result from a combination of landsliding and soil creep along with fluvial action on the slopes. Areas of colluvial landforms are also found in sections 29, 32, and 33, T154N, R79W and in places along the valley walls of the Souris River meltwater trench.

SYNOPSIS OF GEOLOGIC HISTORY

Preglacial History

The Precambrian, Paleozoic, and Mesozoic history of McHenry County is summarized earlier in this report, in the section dealing with stratigraphy. During early Tertiary time, some marine sediments were deposited in the Cannonball sea. It is not known how much area they originally covered, but they are found today over the southwest third of the county. Nonmarine Bullion Creek Formation sediments were deposited on top of the Cannonball shales; these are found today over the southwest corner of the county, but they may have been more extensive before the area was subjected to post-Paleocene erosion.

Erosion probably continued, intermittently, during much of Tertiary time in McHenry County, through most of Pliocene time. By the end of the Pliocene Epoch, a gently rolling landscape had developed on the late Cretaceous and early Paleocene sands and shales of the Fox Hills, Hell Creek, Cannonball, and Bullion Creek Formations. The land surface sloped gently northeastward from about 2,000 feet in the south and west to per-

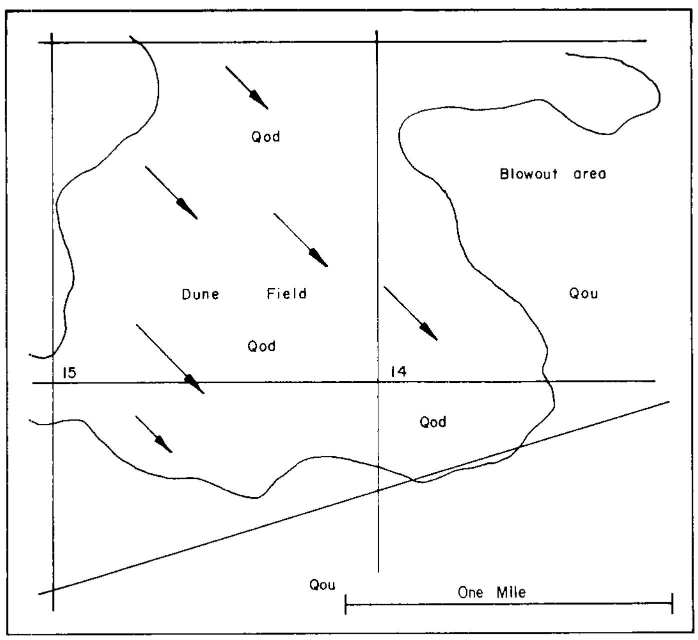
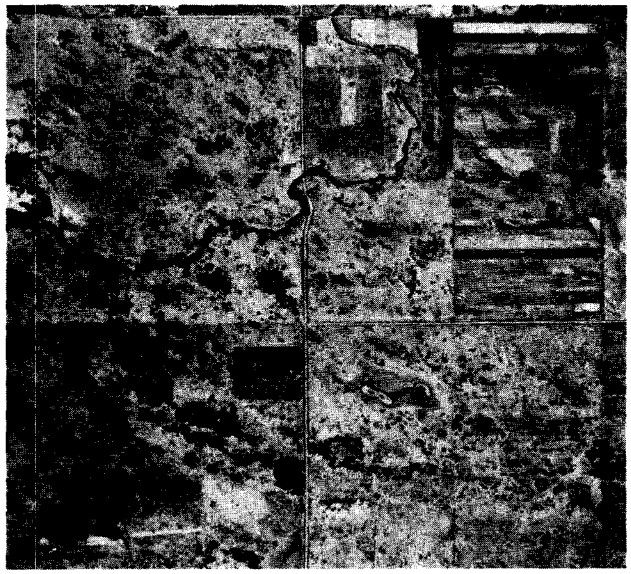


Figure 17. Dune field about two miles northeast of Denbigh (secs 14 and 15, T156N, R77W). The small arrows show the orientation of the dunes, the prevailing wind direction. These dunes are as much as 50 feet high. Vegetation is restricted mainly to the north slopes.



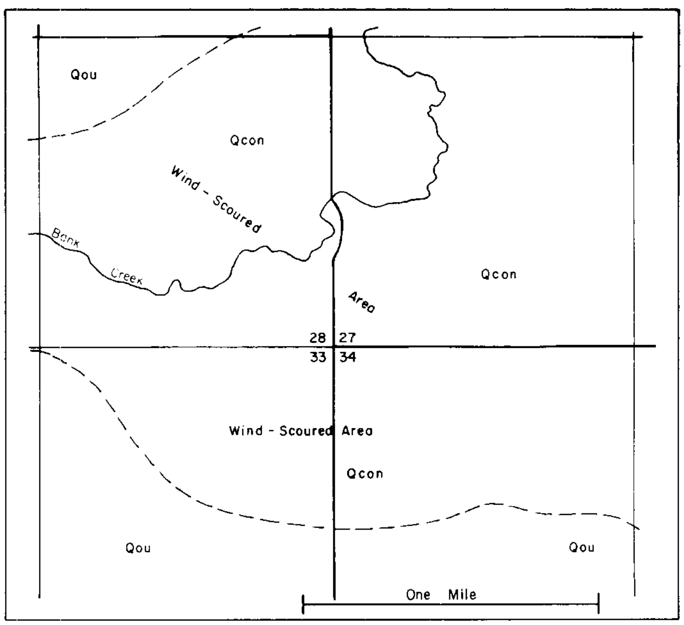


Figure 18. Wind-scoured area of nearshore to offshore lake sediment (turbidity current sediment is generally exposed in this area), west of Bantry (secs 27, 28, 33, and 34, T158N, R78W). Many blowout depressions are found in the area designated "Wind-Scoured Area." The overall northwest-southeast grain resulting from wind erosion is also apparent.

haps 1,500 feet in the northeast part of the county. It does not appear that any prominent escarpment corresponding to the modern Missouri Escarpment existed on the preglacial bedrock surface.

Glacial History

In spite of the relatively large amount of test-hole data available from McHenry County, it was not possible to definitely identify any preglacial valleys. The valleys that can be identified on the bedrock surface (pl. 2) appear to have resulted from glacial diversion of the drainage. In the area where the Fox Hills Formation subcrops beneath the glacial drift, relief on the preglacial bedrock surface is extremely flat, generally less than 5 feet in a mile. A 100-foot, southwesterly rise occurs on the preglacial surface along the Hell Creek subcrop, rising from about 1,400 feet on the Fox Hills to over 1,500 feet on the Cannonball plateau.

The broad lowland that contains the glacial Lake Souris plain in the northern half of McHenry County is an area of anomalously thin Coleharbor Group sediments. The Coleharbor Group sediments average about 65 feet thick beneath the lowland, compared to over a hundred feet thick in most of the adjacent counties (Bottineau County: average thickness of 160 feet; Pierce County: 101 feet; Sheridan County: 270 feet; Ward County: 175 feet; and McLean County: 90 feet). It appears that the occurrence of the lowland can be largely accounted for due to the relatively thinner glacial cover in the area; the bedrock surface beneath the glacial cover is at about the same elevation as it is in adjacent areas.

The reasons for the presence of the glacial Lake Souris lowland are not entirely clear. Possibly, the presence of the Turtle Mountains to the northeast and the Missouri Coteau to the southwest restricted the flow of the glacial lobes somewhat, keeping them from overriding the McHenry County area quite so often or as vigorously as did the glaciers in nearby areas. The Late Wisconsinan surface morphology of the area clearly reflects the influence of the Turtle Mountains and Missouri Coteau; the two uplands appreciably affected the directions of flow of the latest Wisconsinan glaciers. The amount of drift deposited by the several pre-Late Wisconsinan Pleistocene glaciations was probably less in McHenry County as a result of repeated, restricted or diminished, glacial movement through the area. This is probably the main reason for the presence of thinner accumulations of glacial deposits in the area.

Late Wisconsinan History

Shortly after the glacier on the Missouri Coteau in McHenry County stagnated, most of the ice on the lowland northeast of the Coteau melted over about the southeast third of McHenry County. The active ice margin may have receded at least as far as the position of the present Souris River Valley near Velva. At least some large blocks of stagnant ice, some probably rather thick, remained in the area southeast of the glacier, well into northern Sheridan County and western Wells County. Some ponding may have occurred in eastern McHenry County at the time the margin receded to the Velva area (fig. 19). Meltwater streams flowing southeastward carried overflow from these ponded areas. The routes of the meltwater streams are verified by the presence of kettle chains (pl. 1).

When the glacier rapidly readvanced over all of McHenry County except the Missouri Coteau, which remained covered by thick, debris-covered stagnant ice, an episode of fluting and thrusting occurred. The readvance also resulted in a thin 2- or 3-foot-thick or less, layer of sandy till being deposited in many places. It was largely the hydrologic conditions that determined whether fluting or thrusting occurred in any given place. These hydrologic conditions were governed by such things as the position of residual stagnant ice in the area of readvance, permeability of the sedimentary layers beneath the ice, permafrost conditions, and the rate at which the readvance occurred.

Generally, the readvancing ice overrode an area in which the groundwater was confined by a layer of either 1) permafrost, or 2) broad areas of stagnant glacial ice, or possibly a combination of the two, or a layer of some otherwise impermeable material. Groundwater was confined and unable to escape to the ground surface ahead of the advancing glacier and, as a result, the pore pressure was raised. In some places, high pore-water pressure forced large blocks of material upward into the path of the advancing glacier, resulting in ice-thrust masses of all sizes. Such ice-thrust masses are particularly abundant in northern Sheridan County. A "classic" example is found in McHenry County at Anamoose, where Steele Lake floods a depression left when material in the hill southeast of the lake was thrust about a half mile from the depression where it originated.

An area outlined by a parallelogram bounded on the corners by the towns of Velva, Verendrye, Drake, and Kief (fig. 20) is unusual in that, in addition to the flutings, which are so spectacular, it has a large number of broad, flat, northwest-southeast trending, sand-filled drainages that are buried under a veneer of sandy till. They are overridden drainage routes.

It seems logical to infer that, as the glacier readvanced rapidly southeastward, groundwater that became trapped beneath the ice in the area (the area bounded by the parallelogram) built up high hydrostatic pressures and resulted in either thrusting by the glacier or streamlining of the surface over which the ice was flowing. The factor determining whether thrusting or fluting occurred was probably only a slight differ-

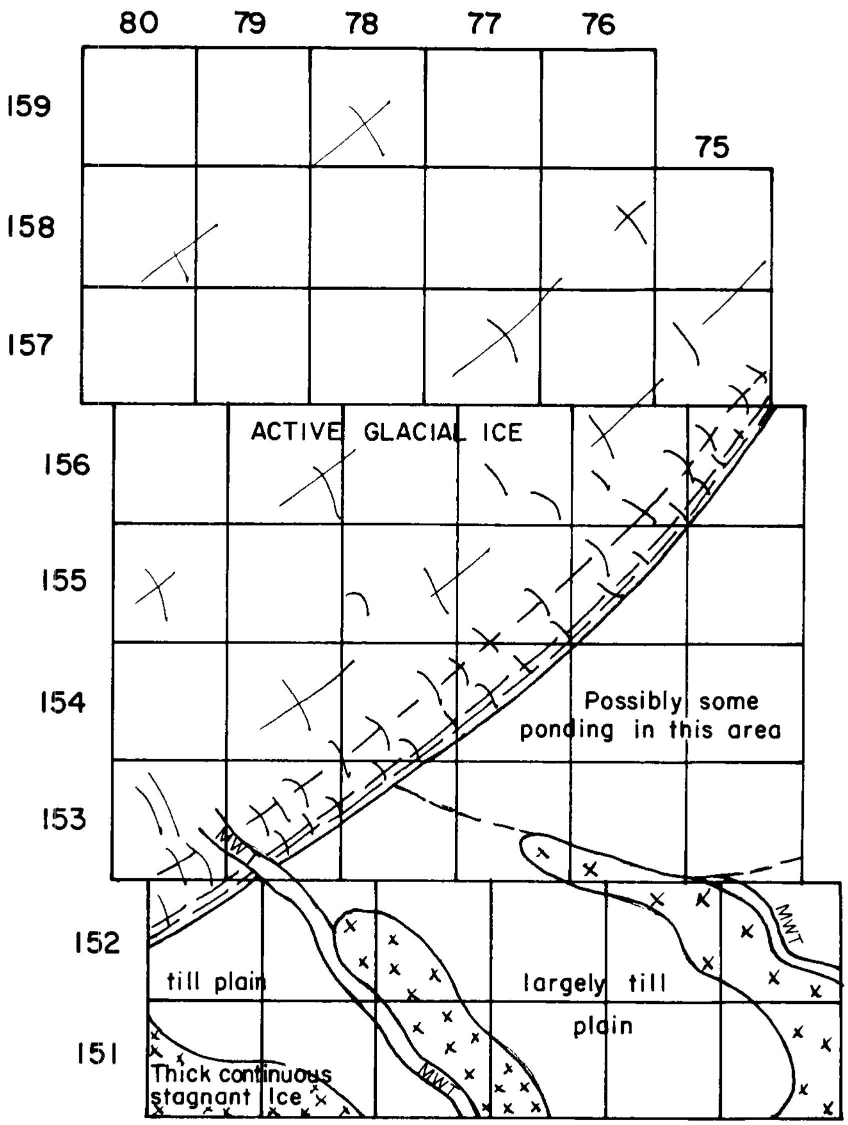


Figure 19. Late Wisconsinan time. Active ice margin receded to someplace in central McHenry County, leaving thick stagnant ice on the Missouri Coteau and discontinuous stagnant ice on the lowland northeast of the Missouri Coteau.

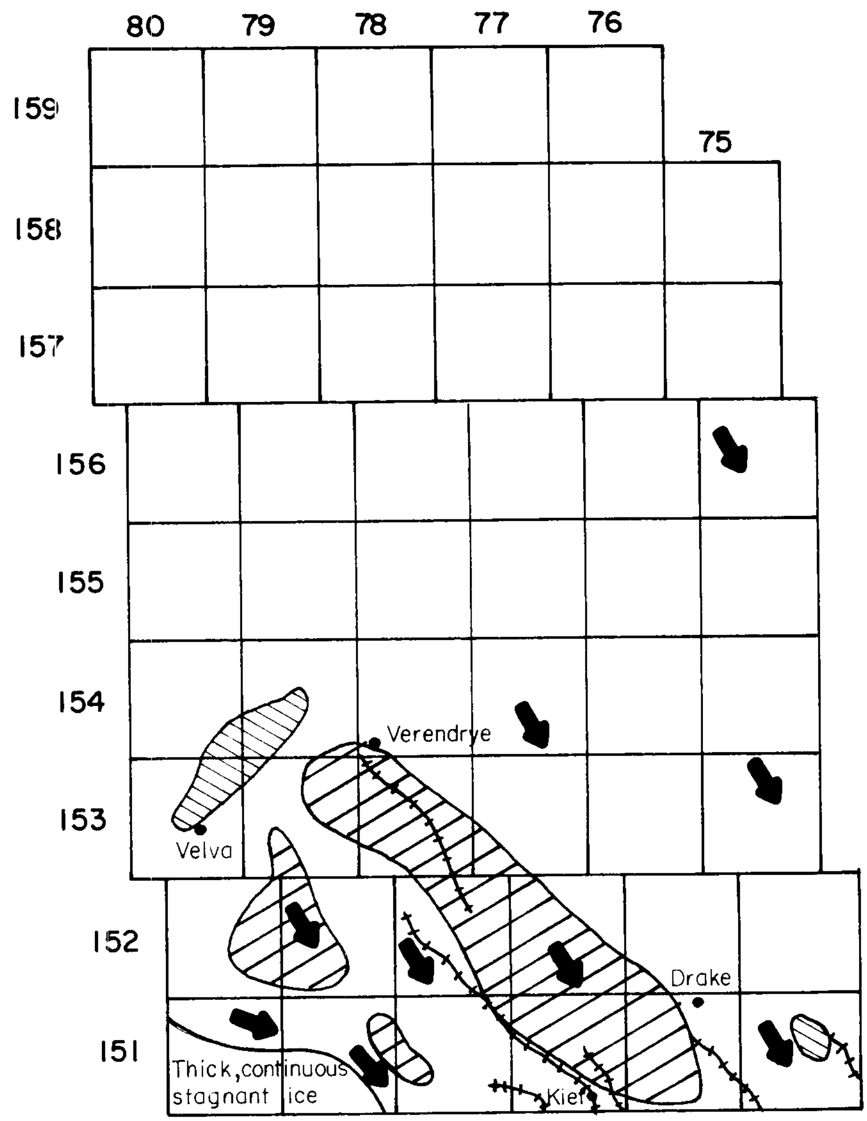


Figure 20. Readvance of the Late Wisconsinan glacier. Depending on certain hydrologic conditions, the rapidly readvancing glacier caused thrusting of the subglacial materials (fine-lined areas) or fluting of the subglacial surface (broad-lined areas).

ence in permeability of the material, or perhaps some minor deviation in the weight of the ice, or even its speed of advance.

When the glacier receded once again, the freshly-fluted area in southern McHenry County and the intensely ice-thrust area of northern Sheridan County remained as a result of the readvance that had occurred. As the ice margin receded, the early glacial Lake Souris, or several disconnected smaller lakes, flooded eastern and northern McHenry County, as well as parts of Pierce and Bottineau Counties; although broad patches of stagnant glacial ice remained over much of the area. Runoff from the melting glacial ice, as well as overflow from the glacial lakes, flowed southeastward, depositing relatively small amounts of gravel and sand in places (pl. 1; also stippled areas on fig. 21) and washing the till surface in other places (pl. 1).

Gradually, as the stagnant ice melted, glacial Lake Souris expanded so that it flooded the entire northeastern half of McHenry County. Many streams flowed into the expanding lake, most of them from the west and northwest, delivering a large volume of material, which was deposited nearshore as gravel and sand and in the deeper parts of the lake as offshore, turbidity-current sediment (pl. 1; fig. 22).

When the lake drained, the Souris River flowed out over the lake plain, meandering widely on the flat surface until it settled into a broad, tortuous, northerly route (fig. 23). With drying, the sand of the density-current deposits of the glacial Lake Souris floor were subjected to intense wind erosion. Much of this eolian activity probably occurred during the Holocene hypsithermal event, about 7,000 years ago.

ECONOMIC GEOLOGY

Oil and Gas

McHenry County has one producing oil field, the Pratt Field in the northwestern corner of the county. Production is from the Mississippian Madison pool, which produces from depths of about 4,000 feet. Since it was discovered in 1960, the Pratt-Madison pool has produced just over 500,000 barrels of oil from nine wells (through January 1, 1980; fig. 24). Currently, six wells are capable of production from the pool. Figure 24 shows performance curves of the Pratt-Madison pool since 1970.

In spite of the total of about 110 exploratory wells that have been drilled in McHenry County, the area has not yet been thoroughly explored. All but nine of the test holes that have been drilled have bottomed in Mississippian rocks and all except a dozen or so of these have been located in the northern part of the county. At least 20 townships in the southern half of the

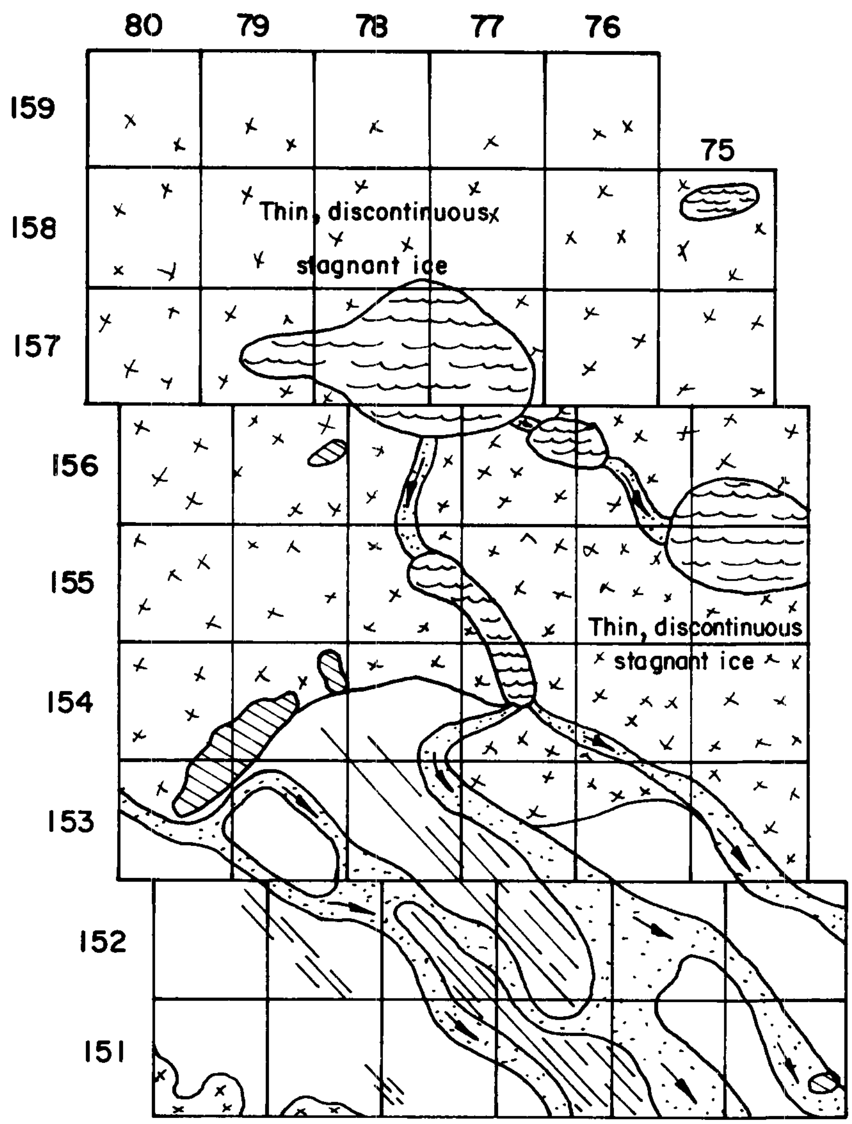


Figure 21. Formation of glacial Lake Souris. When the active glacier receded from McHenry County, much of the northern part of the area was left covered by a discontinuous sheet of stagnant ice. Low areas were flooded by glacial meltwater, and runoff from precipitation, which also overflowed southeastward through drainage channels.

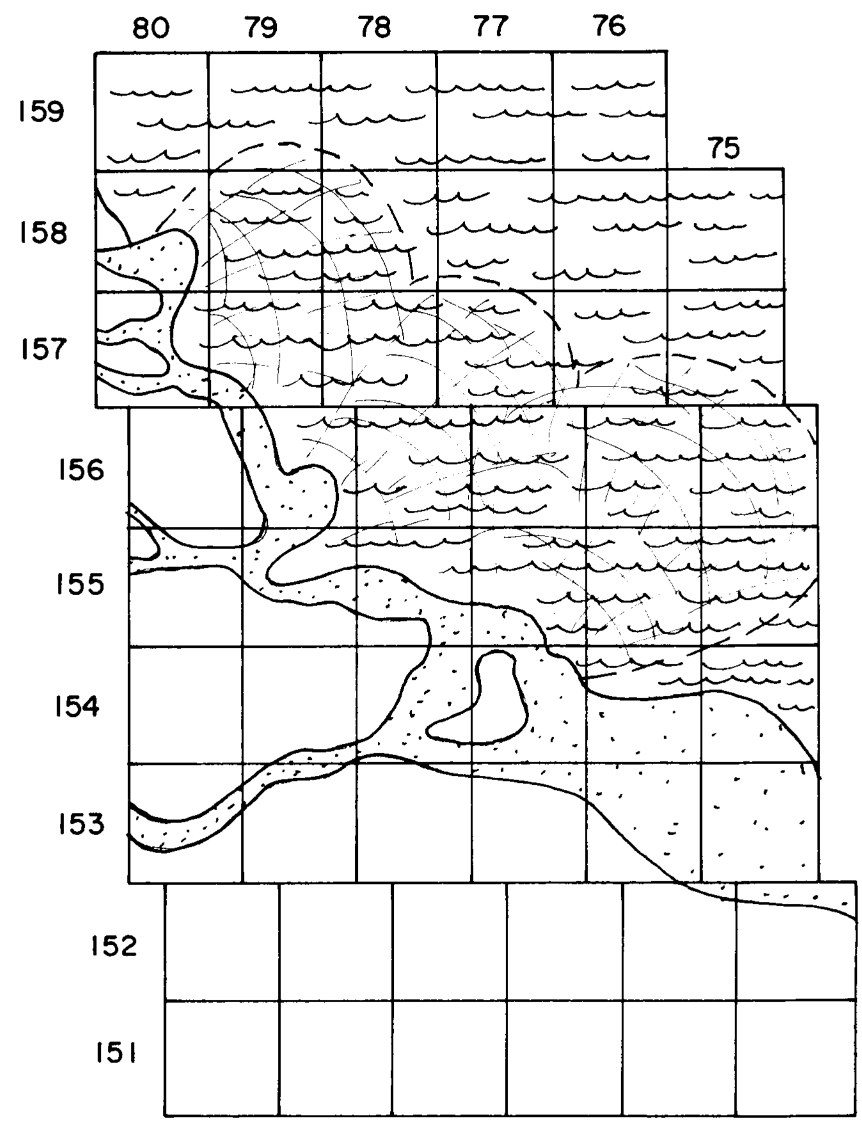


Figure 22. Deposition of turbidity-current sediment. As the stagnant ice melted, glacial Lake Souris expanded into a broad lake, flooding all of northeastern McHenry County. Numerous streams flowing into the lake from the west deposited coarse material along the shore of the lake and fans of finer grained turbidity-current sediment were deposited over much of the lake floor beneath deeper water.

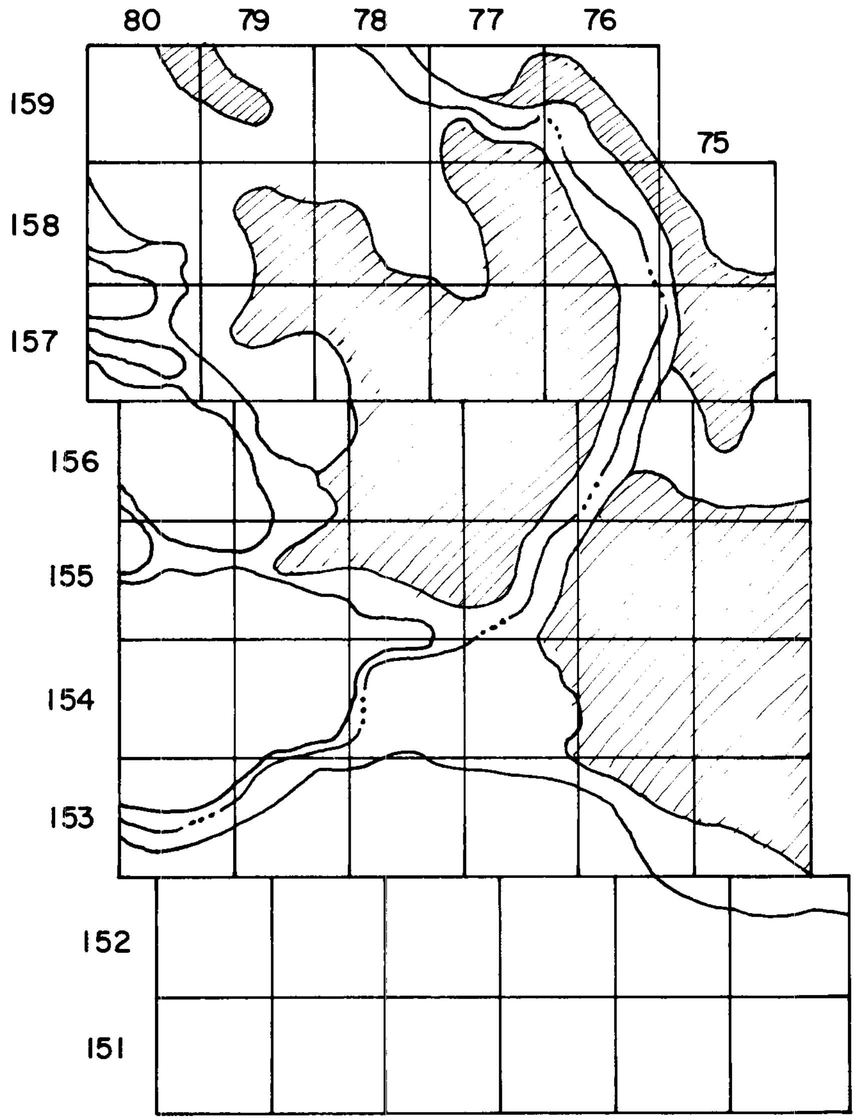


Figure 23. Development of the Souris River Valley. When glacial Lake Souris drained, the Souris River established a northerly route across the lake plain. The route of the river over this nearly flat area changed often, and was extremely tortuous. Also, after the lake drained, broad areas of the former lake floor, largely turbidity fan sediment, were subjected to intense wind erosion, resulting in the building of large dune fields (lined areas).

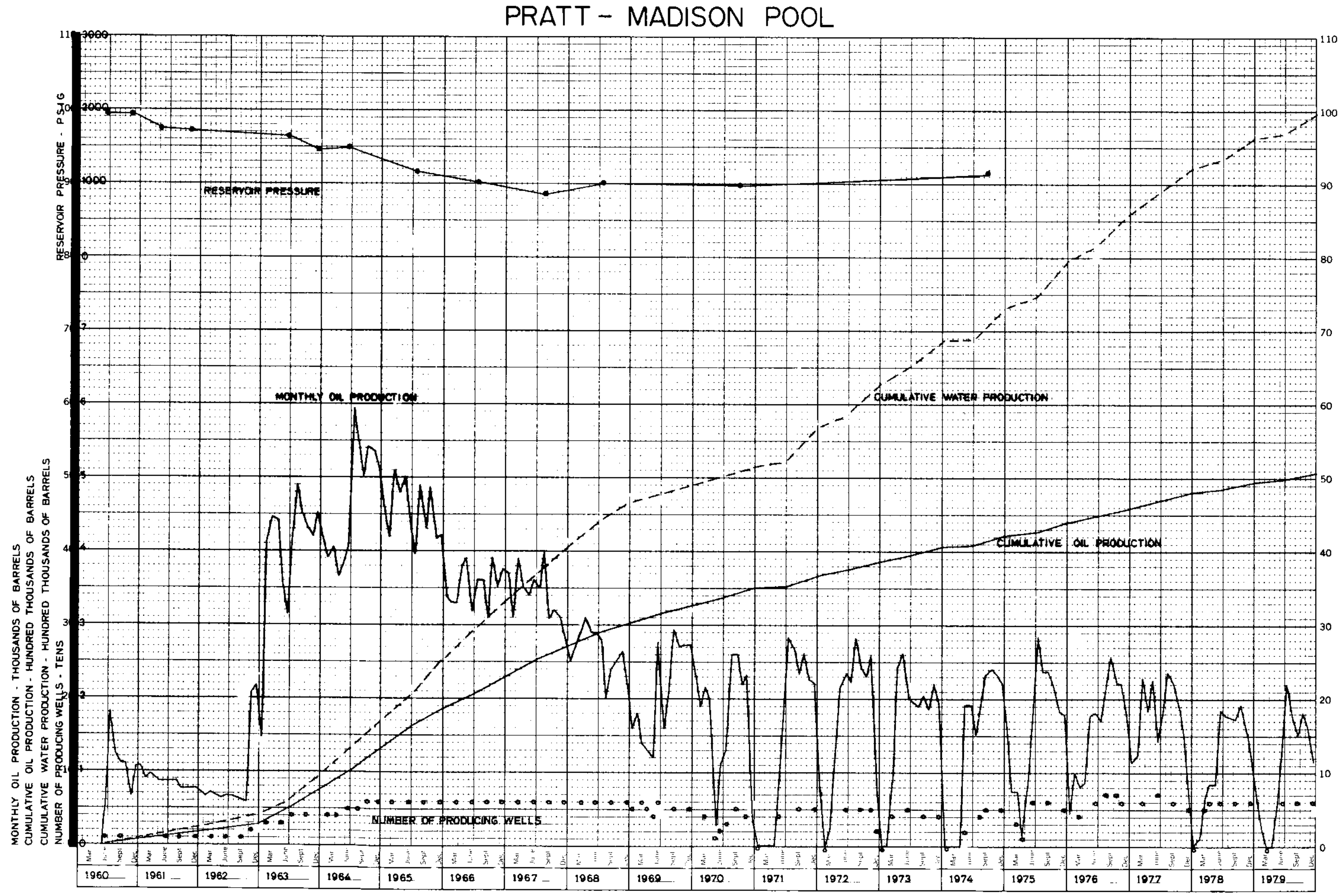


Figure 24. Performance curves for the Pratt-Madison Field, McHenry County.

county have not had a test to any depth. Recent, renewed interest in the area is reflected by current drilling permits which call for test holes deeper than the Mississippian.

Lignite

The lignite-bearing Bullion Creek and Sentinel Butte Formations subcrop beneath the glacial sediment in southwestern McHenry County. It has been calculated that 118 billion tons of lignite coal underlie McHenry County, and 15 billion tons of that is considered to be "strippable." However, the closest production is just across the county line in Ward County. Consolidation Coal Company mined about 335 thousand tons of coal in their Velva mine, located in secs 28, 34, and 35, T152N, R81W, and secs 1 and 2, T151N, R81W, in Ward County during fiscal year 1980 to supply the William J. Neal Power Plant at Voltaire.

In view of the large, strippable tracts of lignite resources in other parts of North Dakota, it is unlikely that McHenry County's relatively small resource will be exploited in the near future.

Sand and Gravel

McHenry County has one of the larger gravel resources in North Dakota. The Souris River, along with other smaller streams, built a series of delta-like wedges of sand and gravel in glacial Lake Souris. However, because of its distance from areas of heavy use of gravel, this deposit has not been fully utilized. Extensive gravel deposits also occur on terraces above the Souris River in the Velva-Verendrye area. The quality of this gravel is generally good.

Small gravel pits operate as the need arises and dozens of these pits are found throughout McHenry County. In 1978, the last year for which production was reported from McHenry County (no operator reported any 1979 production in McHenry County), a total of 26,000 yards of gravel was mined. Most of that came from an esker deposit.

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