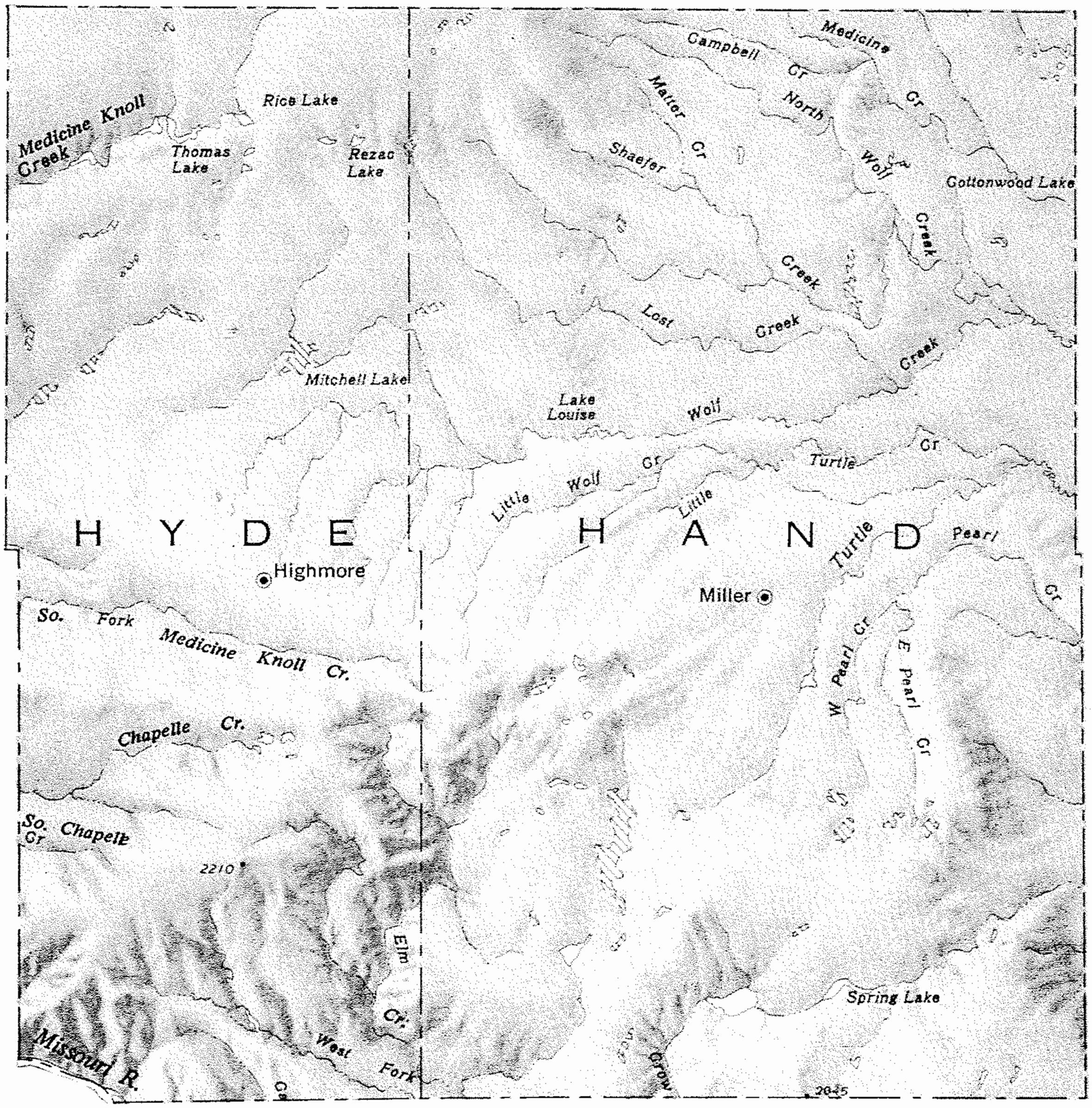
Bulletin 28

Geology and Water Resources of Hand and Hyde Counties, South Dakota Part 1: Geology



by Ronald Helgerson and George E. Duchossois

Prepared in cooperation with the United States Geological Survey,
Oahe Conservancy Sub-District, and Hand and Hyde Counties, South Dakota

DEPARTMENT OF WATER AND NATURAL RESOURCES
SOUTH DAKOTA GEOLOGICAL SURVEY—1987

STATE OF SOUTH DAKOTA
George S. Mickelson, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
John J. Smith, Secretary

DIVISION OF GEOLOGICAL SURVEY
Merlin J. Tipton, State Geologist

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Part I: GEOLOGY

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Hand and Hyde Counties

Science Center
University of South Dakota
Vermillion, South Dakota

1987

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ABSTRACT

Hand and Hyde Counties cover an area of 2,297 square miles in east-central South Dakota. The two-County area is contained in the Great Plains and Central Lowland physiographic provinces. Major topographic features are the Missouri Trench, Great Ree Valley, Ree Hills, Orient Hills, and Wessington Hills. Topographic highs (Ree, Wessington, and Orient Hills) are part of the Coteau du Missouri and the topographic low (Great Ree Valley) is a portion of the James Basin.

The two-County area is covered by Pleistocene and Holocene deposits except for a small portion of Hyde County where the Cretaceous Pierre Shale is exposed. Subcropping the Pleistocene deposits are the Pierre Shale and Niobrara Formation, although the latter only subcrops a very small portion of the study area. Beneath these are rocks that range in age from Cretaceous to Precambrian.

Late Wisconsin glacial deposits comprise most of the surficial deposits. These deposits have a maximum thickness of 500 feet and consist primarily of till and outwash. Recent deposits include alluvial sediments in modern stream valleys and colluvium along the Coteau du Missouri escarpment.

One major glacial advance occurred during late Wisconsin time and covered all of the two-County area. As this ice sheet advanced it blocked existent drainages. This blockage ultimately lead to the formation of the present Missouri River.

As this late Wisconsin ice sheet began to stagnate and recede, it left behind large areas of stagnation moraine. Stagnation of the ice first occurred on the high areas of both Counties and later in the low area in central Hand County. Meltwater from the retreating ice sheet affected the development of the present drainage pattern. In general, the topography and drainage pattern which developed as the ice retreated has not changed since the end of the Pleistocene Epoch.

Primary economic resources found in Hand and Hyde Counties are water and deposits of sand and gravel. Both of these resources (especially water) are of major economic importance. There is no production of, or information indicating the presence of, significant metallic or fossil fuel reserves in the two-County area.

INTRODUCTION

Purpose

Findings of the geologic investigation of Hand and Hyde Counties, South Dakota, are contained in this report. It is one of series of county-wide studies being conducted by the South Dakota Geological Survey. Establishment of a geologic and hydrologic framework on which the development and subsequent use of the mineral and water resources can be based is the primary purpose of this report. Because the geology of an area directly controls the occurrence and quality of ground water, it is hoped that this report will aid in the orderly development and proper management of the water resources. Interpretation of the geologic history and locating and delineating the aquifers in the two-County area were the two major components of this effort. The study was a cooperative effort of the South Dakota Geological Survey, United States Geological Survey, Oahe Conservancy Sub-District, and Hand and Hyde Counties.

Five separate publications stem from this investigation. They are: **Major Aquifers in Hand and Hyde Counties, South Dakota** (Koch, 1976), **Sand and Gravel Resources in Hand County, South Dakota** (Schroeder, 1976a), **Sand and Gravel Resources in Hyde County, South Dakota** (Schroeder, 1976b), **Geology and Water Resources of Hand and Hyde Counties, South Dakota: Part II, Water Resources** (Koch, 1980), and **Geology and Water Resources of Hand and Hyde Counties, South Dakota: Part I, Geology** (this report). The first three contain a generalized summary of aquifer data and distribution of surficial sand and gravel deposits. Part I contains the geologic findings, and Part II (Koch, 1980) contains an evaluation of the water resources. All of the original data generated during this study and preexisting data compiled for these reports are available at the South Dakota Geological Survey in Vermillion and the United States Geological Survey in Huron.

Location

Hand and Hyde Counties are located in east-central South Dakota (fig. 1). Hand County contains 1,436 square miles and Hyde County 861 square miles.

Physiography and Topography

Hand and Hyde Counties (fig. 1) are in the Coteau du Missouri division of the Great Plains Physiographic Province and the James Basin division of the Central Lowland Physiographic Province (Fenneman, 1931). Most of the two-County area has a flat to gently rolling surface.

The Coteau du Missouri is a highland which trends north-south through both North Dakota and South Dakota and varies in width from 25 miles to 80 miles. It comprises the western three-fourths of the study area. The James Basin is approximately 500 feet lower in elevation than the Coteau du Missouri and includes the eastern one-fourth of the study area. Transition from the James Basin to the Coteau du Missouri is gradual in the central portion of the two-County area. This broad, low area is called the Great Ree Valley (fig. 2) and is bounded on the north by the Orient Hills and on the south by the Ree and Wessington Hills.

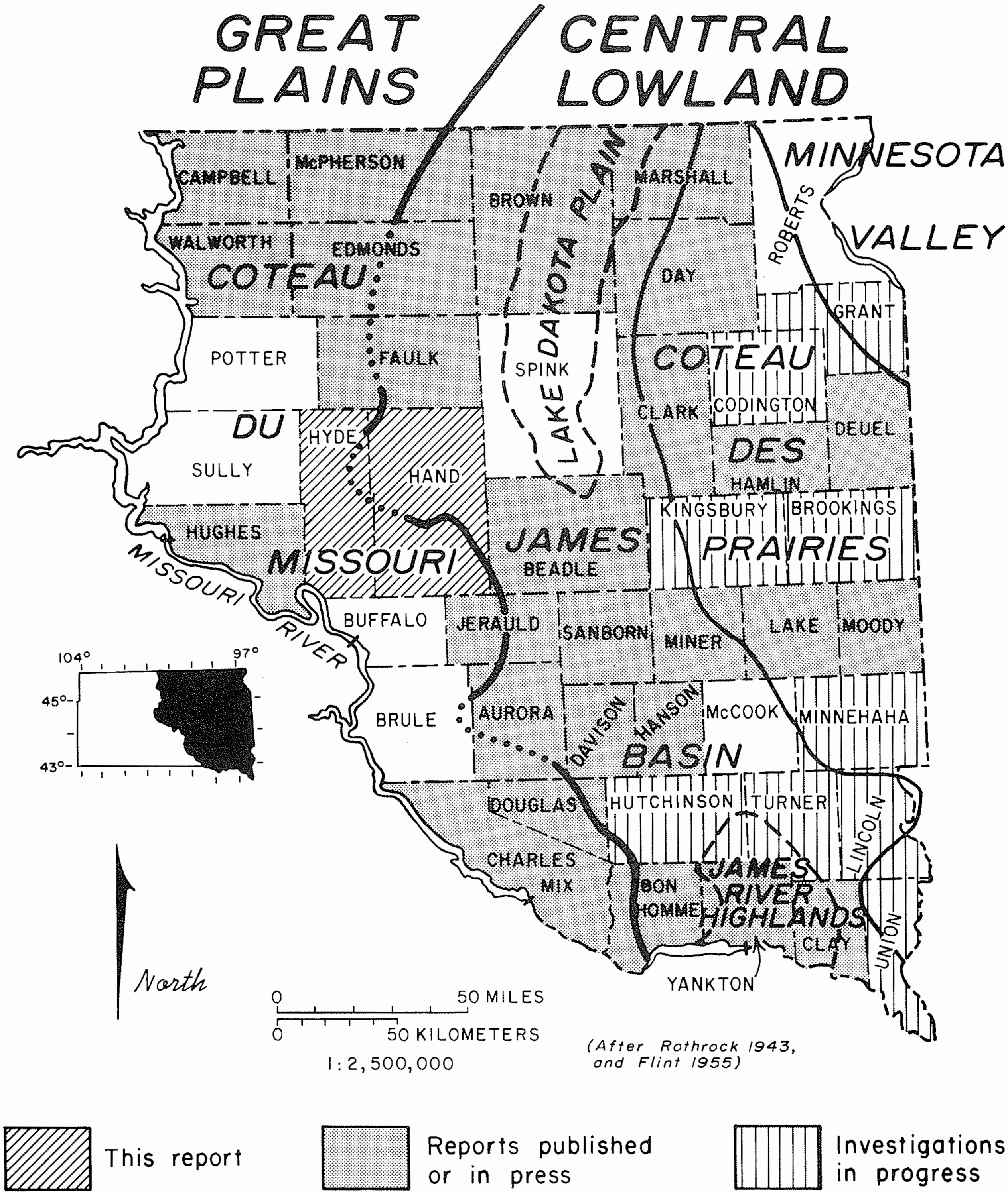
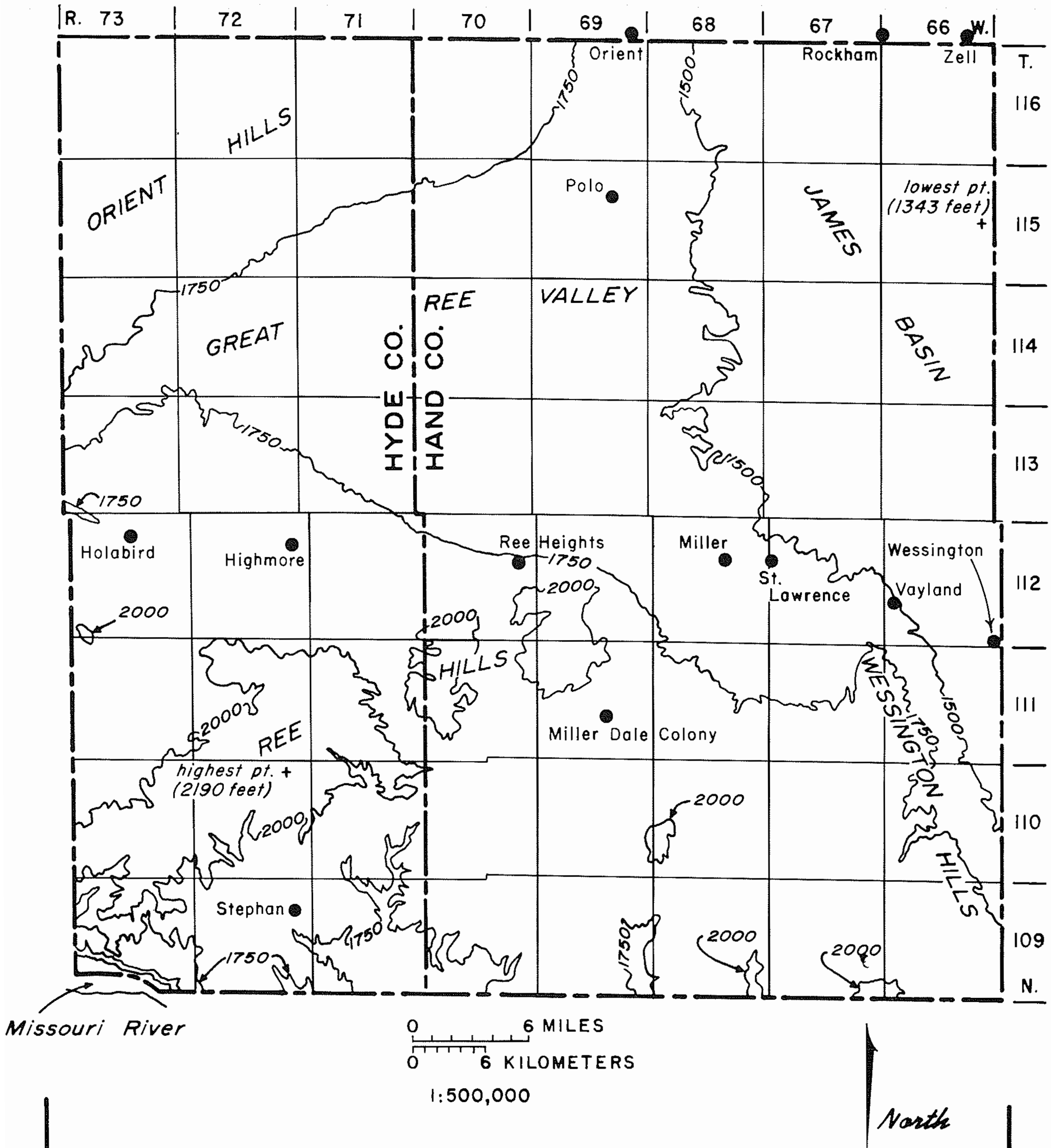


Figure 1. Index map of eastern South Dakota showing area of this report, status of county investigations, and major physiographic divisions.



Topographic contour - shows elevation of land surface. Contour interval = 250 feet. Datum is mean sea level.

Figure 2. Physiographic features of Hand and Hyde Counties.

Another conspicuous topographic feature is the Missouri River Trench. Extreme southwestern Hyde County is bounded by the Missouri River impoundment of Lake Sharpe, which has a normal pool elevation of 1,420 feet and is approximately 700 feet lower than the highlands adjacent to the river. This represents the maximum relief; whereas, most of the study area has a gently sloping surface with low local relief. The highest point in the two Counties occur on Ree Hills, south-central Hyde County, at an elevation of 2,190 feet and the lowest point is in northeastern Hand County, at an elevation of 1,343 feet.

Previous Investigations

Lewis and Clark were probably the first of several early investigators to describe the geology and landforms of the study area (Thwaites, 1959). This early description was very general and confined to the area immediately adjoining the Missouri River. Several state-wide and regional studies have included all or portions of Hand and Hyde Counties, the earliest of which was done by Chamberlin (1883). Chamberlin's work preceded reports by Todd (1885, 1894, and 1896), Darton (1896, 1905, and 1909), Rothrock (1943), and White (1963). The most recent reconnaissance study of this area was done by Flint (1955) who mapped the Pleistocene deposits of the eastern half of South Dakota.

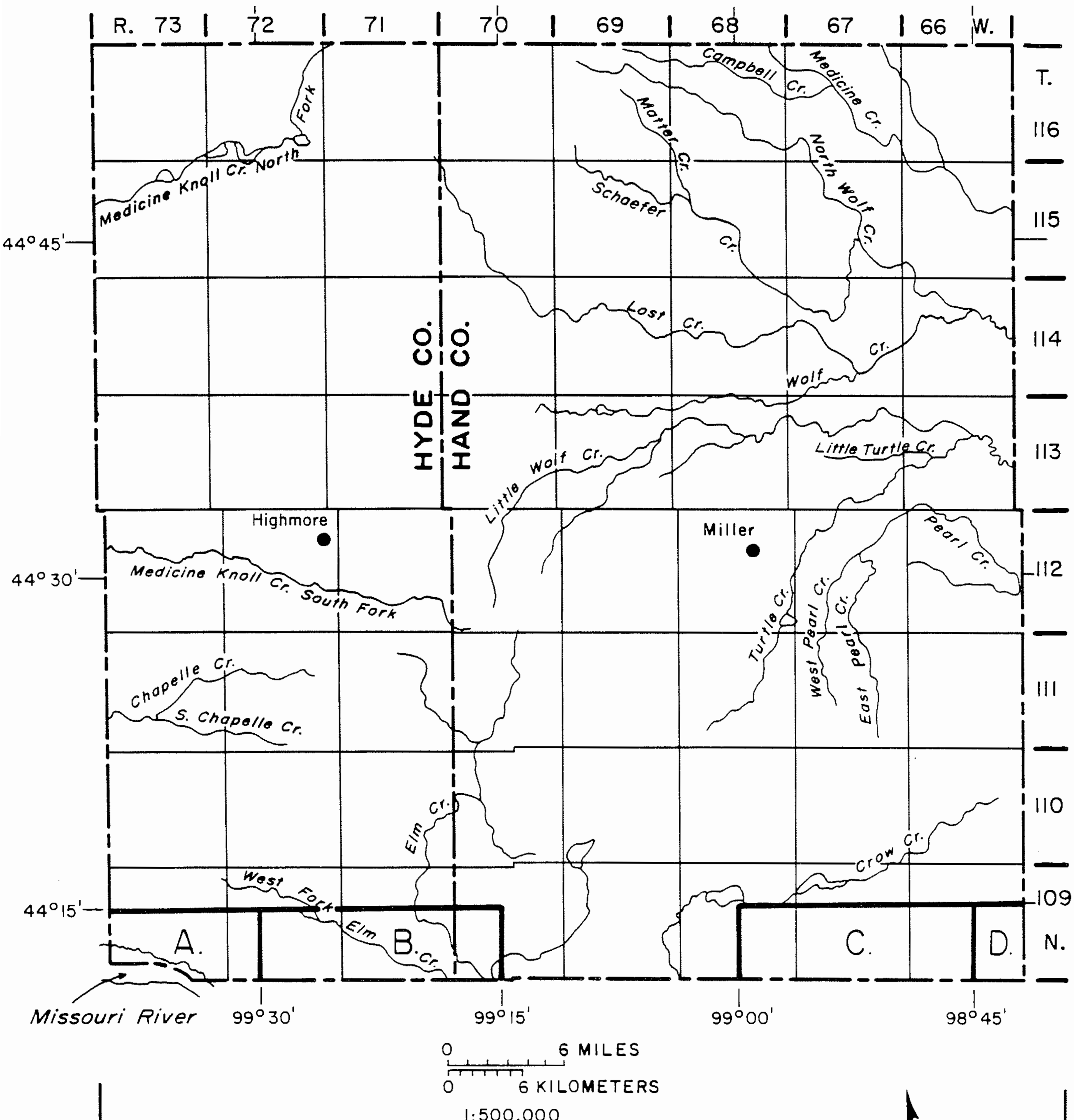
Portions of the two-County area were included in geologic investigations of a more localized nature. Four maps in a series of 15-minute quadrangle geologic maps prepared by the South Dakota Geological Survey cover a small part of southern Hand and Hyde Counties (fig. 3). Also, a water-supply study for the City of Miller in Hand County was conducted by the South Dakota Geological Survey (Christensen, 1962).

Several detailed studies have been conducted on the Ree Marl, which is a Pleistocene lake deposit southwest of Ree Heights in Hand County. The earliest investigator was Cope (1891) and the next published report was by Uyeno and Miller (1963). More recent work dealing with this deposit was done by Ossian (1973).

Methodology

Most of the data for this study were generated during the summer field seasons of 1972 through 1975. In addition, preexisting data on both the surface and subsurface geology of the area were compiled and used in the preparation of this report. Much of this information was obtained from well records of private drillers and from several state and federal agencies. Sites referred to in this report are located using the method described in figure 4.

Information used to determine the geology of the two-County area included outcrops, drill holes, hand-auger holes, soil



A. Lower Brule Quadrangle (Petsch and Curtiss, 1950)

B. Stephan Quadrangle (Curtiss, 1951)

C. Gann Valley Quadrangle (Hoff, 1960)

D. Wessington Springs Quadrangle (Steece, 1967)

Figure 3. Surficial drainage in Hand and Hyde Counties and locations of geologic quadrangle maps.

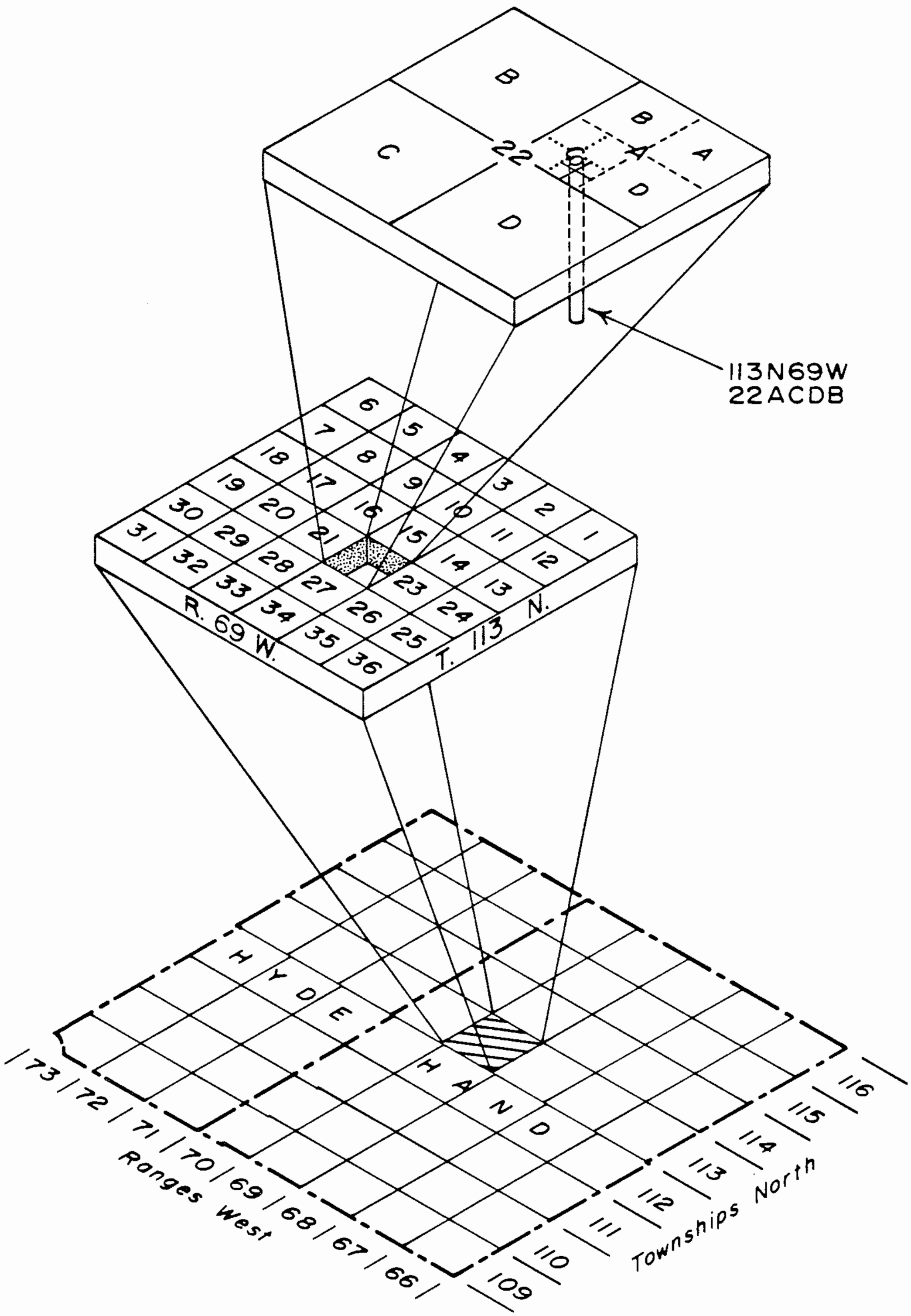


Figure 4. Site-location diagram. The site number consists of township number followed by 'N' for north, range number followed by 'W' for west, section number, and a maximum of four uppercase letters that indicate, respectively, the 160, 40, 10, and 2½-acre tracts in which the site is located. These letters are assigned in a counterclockwise direction beginning with 'A' in the northeast corner. The legal location for 113N69W22ACDB is NW SE SW NE, section 22, T. 113N., R. 69W. An optional serial number following the last letter is used to distinguish between test holes at the same site.

surveys (White and others, 1963; Machlis and Williams, 1925), aerial photograph interpretations, and a thorough reconnaissance of the area. Mapping was done on aerial photographs having an approximately scale of 1:70,000 (1 inch = 1.1 miles). Seven and one-half minute topographic maps and soils maps of the two Counties were used to facilitate aerial photograph interpretation.

Subsurface data were provided by an extensive drilling program and were supplemented by a water-well survey conducted by the United States Geological Survey (Koch, 1980). A total of over 50,000 feet was drilled and more than 200 test holes were drilled to bedrock (pl. 1). Rotary-drilling equipment was used in most of the holes drilled to bedrock and auger rigs were used for the shallower drilling. Geophysical logs (single point resistivity, spontaneous potential, and natural gamma) provided additional information and greatly facilitated interpretation of the drilling data.

Acknowledgements

The investigation and preparation of this report were performed under the supervision of Duncan J. McGregor and Merlin J. Tipton, State Geologists. The writers wish to thank the entire staff of the South Dakota Geological Survey for all the assistance provided. A special thanks to Cleo Christensen, Lynn Hedges, Dennis Beissel, and Merlin Tipton for their ideas and guidance. Neil Koch of the U.S. Geological Survey provided much information and advice which is gratefully acknowledged.

Initiation of the study was requested by the Hand and Hyde County Commissioners. Cooperation and information provided by the Commissioners and the residents of the two Counties were greatly appreciated.

Financing of this project was made possible by the cooperation of the South Dakota Geological Survey, United States Geological Survey, Oahe Conservancy Sub-District, and Hand and Hyde Counties.

STRUCTURE

The Precambrian surface in Hand and Hyde Counties dips northwest at an average of 15 feet per mile (Steece, 1961), indicating that the study area is on the extreme southeastern edge of the Williston Basin. In the northern part of the study area, the Greenhorn Limestone dips to the northwest at about 3 feet per mile, conforming with the topography of the Precambrian surface. The southern border of the two-County area is near the northern edge of the west-northwest trending Sioux Ridge (fig. 5). This is a relatively high area on the Precambrian surface that extends from the Sioux Falls area in eastern South Dakota to approx-

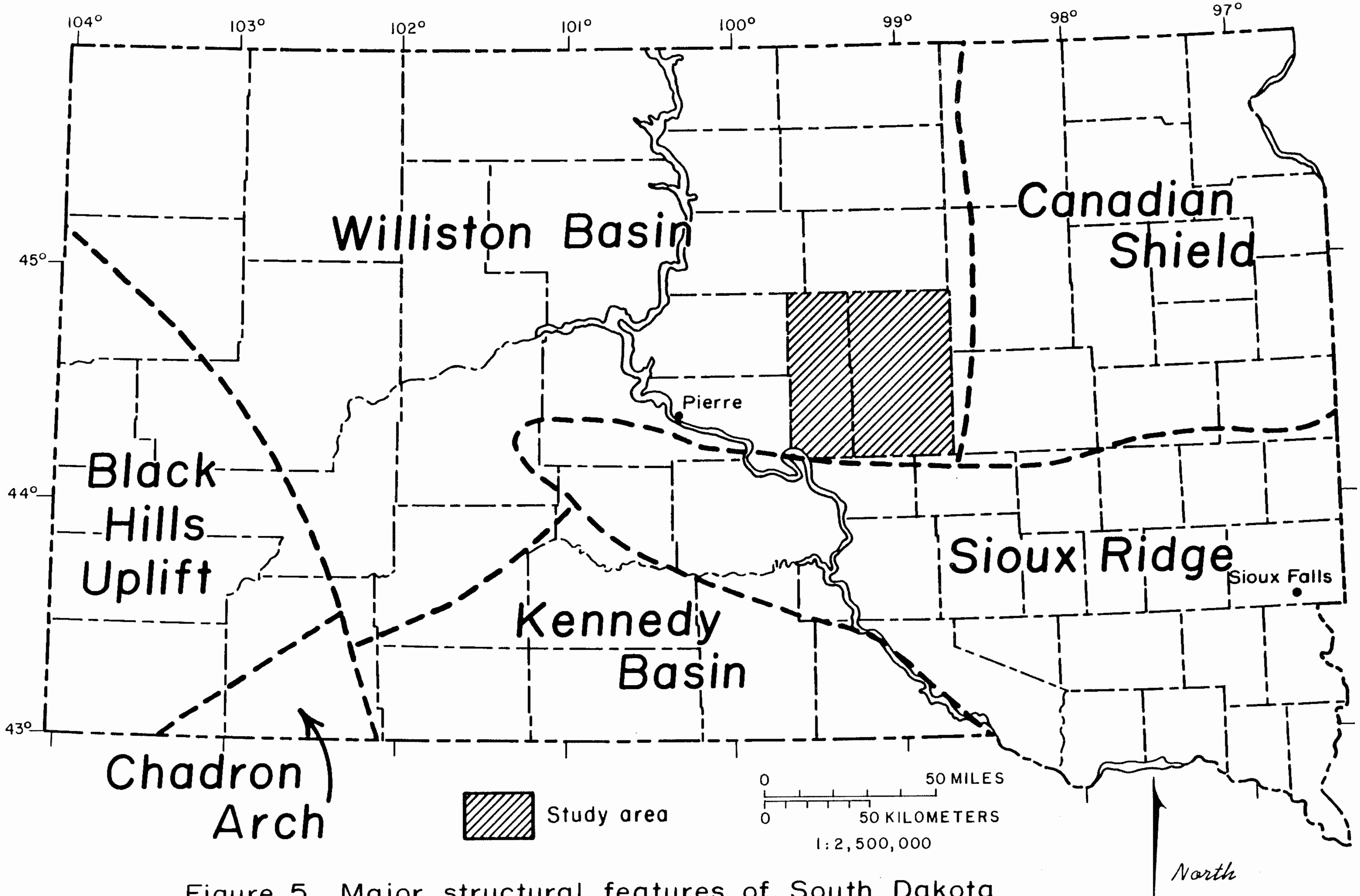


Figure 5. Major structural features of South Dakota (modified from Steece, 1975).

imately 50 miles west of Pierre and attains a maximum width of approximately 75 miles. This ancient topographic high influenced the depositional history of surrounding areas, including Hand and Hyde Counties.

Minimal detailed structure information is available for the study area, however, a magnetometer survey indicates several anomalies (Petsch, 1967). The largest of these is a magnetometer high in northwestern Hyde County. Future deep drilling and geophysical studies will undoubtedly refine the current generalized structural data now available for the area.

STRATIGRAPHY

Stratigraphic Relations

Stratigraphic nomenclature used in this report conforms to that accepted by the South Dakota Geological Survey and to the North American stratigraphic code (North American Commission on Stratigraphic Nomenclature, 1983).

This report concentrates on the Pleistocene deposits for two primary reasons. First, these deposits are present at the surface and contain abundant water and aggregate resources. In order to fully utilize these resources, the distribution and mode of deposition of the deposits in which they occur must be known. Secondly, glacial deposits are extremely variable and require detailed study to achieve a reasonable level of predictability with respect to occurrence, thickness, and type of material.

Bedrock Units

Table 1 is a generalized stratigraphic section which lists all of the bedrock deposits known to occur in Hand and Hyde Counties. Little is known about the deposits below the Dakota Formation in Hand and Hyde Counties because of the absence of detailed drill hole information. Therefore, these deposits will not be described here. The reader is referred to Agnew and Tychsen (1965) for descriptions of these deposits.

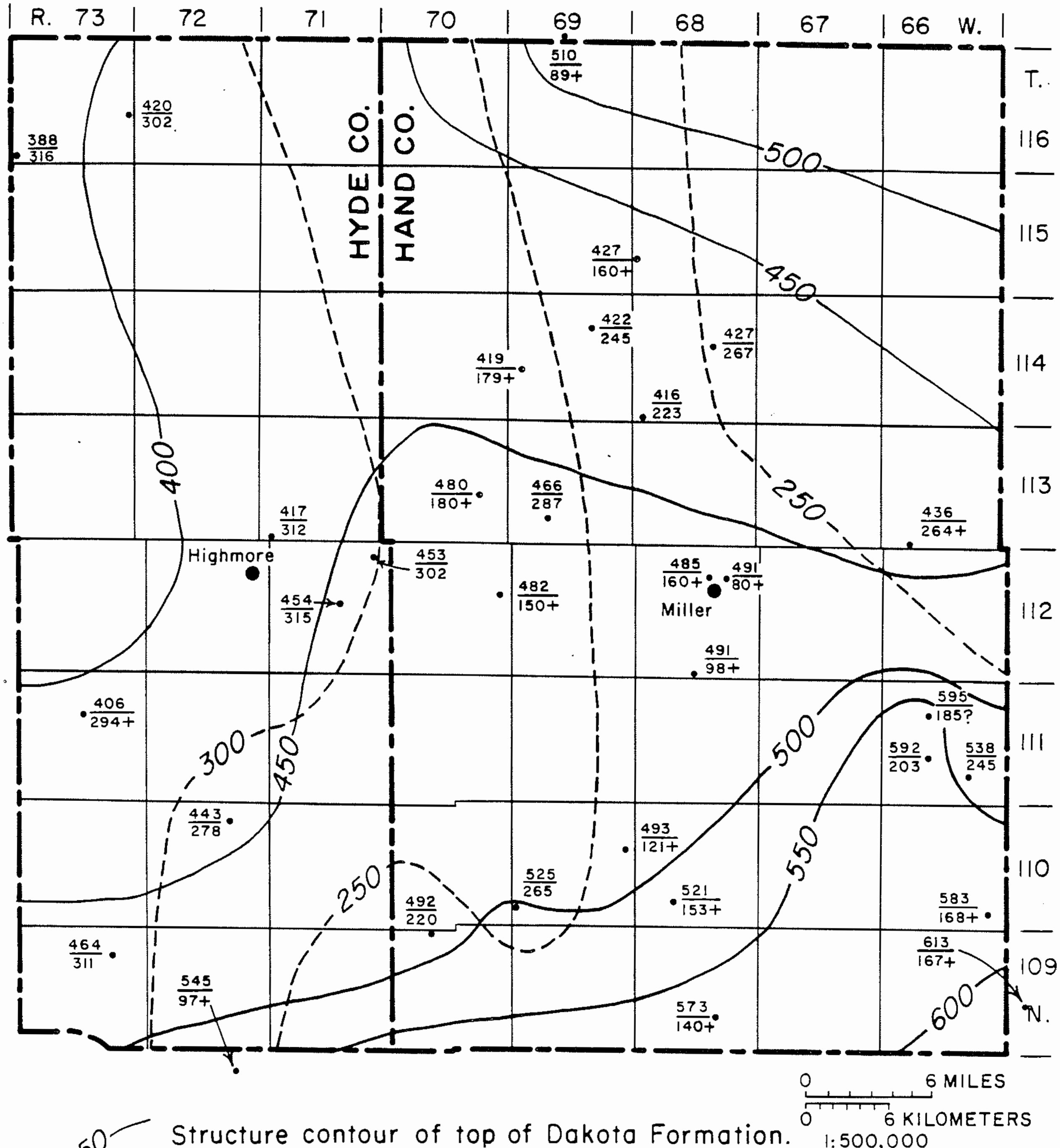
Dakota Formation

The Dakota Formation consists of interbedded sands, siltstones, and shales. It was first described by Meek and Hayden (1861) from an exposure in Dakota County, Nebraska, and it attains a maximum thickness of approximately 320 feet in the study area (fig. 6). Due to its large lateral extent and the large number of flowing wells developed in it, the Dakota Formation has been subject to considerable study and controversy. The reader is referred to Schoon (1971) for a detailed treatment of the stratigraphy of the Dakota Formation and to Koch (1980) for

Table 1. Principal bedrock units in Hand and Hyde Counties.

Period	Bedrock Unit	Description	Min. and Max. Known Thickness in Study Area (in feet)
1.			
Late Cretaceous	Pierre Shale	Claystone	220-710
Late Cretaceous	Niobrara Formation	Marl	65-155
Late Cretaceous	Carlile Shale	Claystone	140-320
Late Cretaceous	Greenhorn Limestone	Shale, calcareous	70-120
Late Cretaceous	Graneros Shale	Shale	190-305
Early Cretaceous	Dakota Formation	Sandstone and Shale	200-320
Early Cretaceous	Skull Creek Shale	Shale	25-125
Early Cretaceous	Inyan Kara Group	Sandstone and Shale	80-240
1.			
Permian Pennsylvanian	Minnelusa Formation	Sandstone, Limestone, and Shale	0-175
Mississippian	Madison Group	Limestone	0-55
1.			
Ordovician	Red River Limestone	Dolomite and Limestone	0-215
Ordovician	Winnipeg Formation	Shale and Sandstone	0-125
1.			
Precambrian		Granitic gneiss and variable metamorphic rocks[2].	- - - -

1. Major period of erosion or non-deposition.
2. Lidiak (1971).



450 Structure contour of top of Dakota Formation. Contour interval = 50 feet.

250 Isopach for the Dakota Formation. Contour interval = 50 feet.

492/150+ Data points. Top number is elevation of top of Dakota Formation in feet above mean sea level. Bottom number is thickness of Dakota Formation in feet; a plus sign (+) indicates partial thickness. All data interpreted from electric logs on file at South Dakota Geological Survey.

Figure 6. Structure-contour and isopach map of the Dakota Formation in Hand and Hyde Counties.

information regarding its use as an aquifer in Hand and Hyde Counties.

Graneros Shale

The Graneros Shale is an argillaceous, or clayey, gray shale with very minor amounts of sand. It was first described by Gilbert (1896) from an exposure near Graneros Creek, Pueblo County, Colorado. Four members are recognized within the formation in western South Dakota, however, they are not recognized in the study area. The formation has an average thickness of approximately 250 feet in the two-County area.

Greenhorn Limestone

Greenhorn Limestone consists of thin layers (less than 1 foot of slabby, fossiliferous limestone separated by layers of calcareous shale. It was first described by Gilbert (1896) from an exposure near Greenhorn Station, 14 miles south of Pueblo, Colorado. The Greenhorn Limestone is noted for the fossil _Inoceramus labiatus_, which aids in the recognition of this unit. The great lateral extent and the physical and geophysical characteristics of the Greenhorn Limestone make it an ideal marker bed in much of South Dakota. All of Hand and Hyde Counties are underlain by this unit and its average thickness is approximately 100 feet.

Carlile Shale

The Carlile Shale is composed of medium- to dark-gray, plastic, fissile, claystone, and it was first described and named by Gilbert (1896) from an exposure near Carlile Spring and Carlile Station, Colorado. Several members are recognized in the Carlile Shale in western South Dakota, however, only the Codell Sandstone Member, a relatively thin sand and clayey-sand unit, is recognized in the study area. The remainder of the formation is undivided.

Niobrara Formation

The Niobrara Formation is a gray, speckled marl which is very fossiliferous. In some cases, virtually all of the rock is composed of fossil material. When weathered the formation displays a characteristic buff or yellow-brown color. Meek and Hayden (1861) first described the formation from an exposure along the Missouri River, in Knox County, Nebraska. Three of the most common microfossils contained in the Niobrara Formation are _Globigerina_, _Planomalina_, and _Heterohelix_. Most macrofossils found in this unit are either _Ostrea congesta_ or _Inoceramus gigantica_. The Niobrara Formation is approximately 100 feet thick in the study area and is the oldest rock on which Pleistocene materials have been deposited in Hand and Hyde Counties (pl. 1 and pl. 2, section D-D').

Pierre Shale

The Pierre Shale is composed of a gray- to dark-gray claystone which contains bentonite beds near the base. Meek and Hayden (1861) named the unit the Fort Pierre Formation from exposures near Fort Pierre, South Dakota. The name was abbreviated by later investigators of the Pierre Formation and subsequently called the Pierre Shale. In Hand and Hyde Counties this formation is present in all but a small portion of east-central and northeastern Hand County and approaches 700 feet in thickness. This formation has been subdivided into eight members currently accepted by the South Dakota Geological Survey, which are, in descending stratigraphic order, the:

Elk Butte Member
Mobridge Member
Virgin Creek Member
Verendrye Member
DeGrey Member
Crow Creek Member
Gregory Member
Sharon Springs Member

All of these units (with the possible exception of the Elk Butte Member) are present either at the surface or in the subsurface in the study area. In this study the Pierre Shale members have not been differentiated. The reader is referred to Crandall (1958) for detailed descriptions of the members.

Pierre Shale forms the only Cretaceous exposures in the two-County area. Outcrops of the formation are restricted to the southwestern corner of Hyde County and valleys along the edge of the Coteau du Missouri southwest of Wessington (pl. 3).

Pleistocene Deposits

Pleistocene deposits cover most of Hand and Hyde Counties, and consist of glacial drift which has an average thickness of approximately 200 feet. The greatest thickness encountered in the study area was at 110N66W06BBBB, where 500 feet of glacial drift was observed (pl. 2, cross section E-E').

All of the glacial material at the surface in Hand and Hyde Counties is late Wisconsin in age, and is the result of one major glacial advance. Previous studies (Flint, 1955) indicated that there were at least two major advances of ice in the study area. An extensive drilling program in Hand and Hyde Counties, as well as counties to the north and west of the study area (Christensen, 1977; Hedges, 1972 and 1987; and Duchossois, in preparation), did not discover any information which would indicate two or more advances of ice. The exact age of the glacial deposits could not be determined because no material commonly used for absolute dating was found in the study area. Glacial material in Beadle County with radiocarbon dates of 12,200 and 14,000 radiocarbon years before present (W-1372 and W-1373, Levin and others, 1965) is stratigraphically equivalent to the deposits in Hand and Hyde Counties. The late-Wisconsin age of the glacial deposits in the study area is based on this relationship. Since nomenclature referred to by Flint (1955) is still occasionally used, table 2 is presented to show the relationship among Flint's nomenclature, other recent or commonly referred to nomenclatures, and the nomenclature used in this report.

Pre-Late Wisconsin Deposits

The only Pleistocene deposits encountered in Hand and Hyde Counties that were deposited prior to the glacial advance are found as buried channel fillings. Although poor samples were obtained because the deposits are buried by as much as 420 feet of drift, the material probably consists of shale-rich till or silt with minor amounts of sand and gravel. Initially this material was deposited as alluvium in deep, narrow valleys but was reworked as the glacier advanced over the valleys. Christensen (1977) found similar material in Edmunds and Faulk Counties and tentatively described it as pre-late Wisconsin. Due to the poor samples and the lack of stratigraphically similar material with absolute dates, no age relationship can be made for the reworked alluvium in the study area except that it pre-dates the Wisconsin glacial deposits.

Three test holes indicated the presence of this material in the study area: 112N67W03BBBB, 112N67W10BBBB, and 116N66W21BBBB. (See appendix.) Bedrock elevations in these three test holes are 1,028, 1075, and 1,053 feet above mean sea level, and they represent the lowest bedrock elevations in the area. These are the only three locations where the Niobrara Formation is directly under the glacial drift. The test hole in northeastern Hand County is located in the deepest part of the ancient Grand River system, which was traced north of the study area by Hedges (1972) and Christensen (1977). A separate ancient river system (the ancient Bad River system) is represented by the buried valley in central Hyde and west-central Hand County. This system trends east-west across the two-County area and was traced west of the study area (Duchossois, 1985).

Late-Wisconsin Deposits

All of the Pleistocene deposits in Hand and Hyde Counties are late Wisconsin in age with the exception of the deep channel fillings mentioned in the previous section. They are the direct

Table 2. Wisconsin classifications in South Dakota and other areas.

Time Scale (Radiocarbon years before present)	Crandall (1958) and Flint (1955)	Lemke and others (1965)	Willman and Frye (1970)	Beissel and Gilbertson (in preparation)	Helgerson and Duchossois (this report)
0–5,000	Recent	Postglacial	Holocene		Holocene
10,000	Mankato		Valderan Substage		
	Interval	Advance 6 (Late Wisconsin)	Two Creekan Substage	Late Wisconsin II	
15,000	Cary	Advance 5 (Late Wisconsin)	Woodfordian Substage	Late Wisconsin I	Late Wisconsin
	Interval	Advance 4 (Late Wisconsin)			
	Tazewell	Advance 3 (Late Wisconsin)			
20,000	Interval	Advance 2 (Late Wisconsin)			
25,000	Iowan	Advance 1 (Early Wisconsin)	Farmdalian Substage	Early Wisconsin (?)	Early Wisconsin
30,000			Altonian Substage		

Modified from Beissel and Gilbertson (in preparation).

result of, or are related to, the late Wisconsin ice advance. For the purposes of this report, these deposits have been divided into four major units: till, basal outwash, interbedded outwash, and surface outwash. Glaciolacustrine deposits and loess also are present in the area to a lesser extent than the four major units and were not mapped. The term "drift" refers to any deposit that is the result of glaciation.

TILL

Till found in Hand and Hyde Counties is composed of rock fragments from clay-size to several feet in diameter but is primarily a sandy, silty clay. Till is by far the most abundant glacial deposit and has a maximum thickness of 425 feet (pl. 2). It comprises most of the surface in the two-County area (pl. 3) and is the parent material for most of the soils. Till is yellow to yellow-brown when oxidized and gray when unoxidized, and in most cases the maximum depth of oxidization is approximately 25 feet. Where exposed, the oxidized till is jointed, and secondary gypsum, calcite, and iron staining are common on the joint surfaces. Both the oxidized and unoxidized tills are calcareous.

Primary constituents of till in the study area are shale, limestone, dolomite, igneous and metamorphic rocks, and an abundance of clay minerals. Shale is the most common rock type in the 1-2 mm size fraction, averaging approximately 50 percent.

Two types of till can be distinguished in Hand and Hyde Counties by their mode of deposition. Debris from the basal portion of the glacier was deposited in a subglacial environment under the pressure of the overlying, active ice. The debris in the basal portion of the glacier was essentially 100 percent shale due to the extensive areas in North Dakota and South Dakota where shale was exposed at the surface as the glacier flowed to the south. This is called lodgement till. Till was also deposited by ice which was dead or stagnant. As this ice melted, material which was contained in the ice or carried on the ice was let down forming ablation till. Debris in the upper portion of the glacier and on top of the ice contains material that has been transported great distances by the ice (as much as 1,000 miles). This material consists of a wide variety of rock types, which was mixed with the shale from the base of the ice as the glacier melted. Thus, the ablation till contains a greater variety of rock types than the lodgement till. Geophysical logs of test holes where both of these types of till are encountered confirm the presence of these two distinct types.

OUTWASH

There are three types of outwash in Hand and Hyde Counties: basal, interbedded, and surface. All three consist of varying amounts of sand and gravel with some silt and clay and were deposited by meltwater associated with the glacier. These deposits vary dramatically over very small distances both laterally and vertically because of the mechanics of deposition or because small changes in the regimen of the glacier radically altered the type of material deposited by the meltwater streams.

Basal Outwash

Deposits of outwash lying directly on the Pierre Shale are present in the two-County area. These deposits are the result of sediment-laden meltwater carrying clay, silt, sand, and gravel away from the ice and depositing it on the bedrock surface. Later these deposits were covered with till as the ice sheet advanced over the area. These outwash bodies are discontinuous and underlie approximately 25 percent of the area. They are usually less than 10 feet thick, although the maximum thickness observed in the study area is 73 feet. Grain size ranges from clay-sized material to cobbles, and the material is composed of shale, coal, limestone, dolomite, and igneous and metamorphic rock fragments. But in most areas these deposits consist of silt- to pebble-sized materials with layers of silt and clay. Plate 2 contains cross sections which graphically display the occurrence of this type of deposit. The deposit at 110N66W06BBBB is a special case with 73 feet of coarse pebble and cobble gravel and minor amounts of silt and clay. (See appendix.) It was formed when a meltwater channel cut into the bedrock, deposited the outwash and subsequently was buried by till (pl. 2, cross section E-E').

Interbedded Outwash

Outwash interbedded with till is common in the subsurface (pl. 2), however, these outwash bodies are discontinuous and grade laterally and vertically into till. Deposits of this type attain a maximum known thickness of 67 feet and average between 10 and 15 feet in the two-County area. Grain size is variable, ranging from clay-sized material to cobbles, and the outwash is composed of shale, dolomite, limestone, and igneous and metamorphic rock fragments.

Surface Outwash

Deposits of up to 150 feet of surface outwash are present in the study area, however, only a small portion of the area has outwash present at the surface due to a thin cover of recent sediments. When this occurs, the unit is mapped as alluvium-outwash complex (pl. 3). Grain size ranges from silt-size to pebbles, and the deposit is similar in composition to the basal and interbedded outwash. Surface outwash in the area takes several forms, due to a combination of glacial and glaciofluvial actions. These include valley train, collapsed, and terrace outwash. Most of the surface of the deposits consist of sand and gravel because the finer-grained material was either left in suspension and carried away by meltwaters or eroded by postglacial stream flow.

LAKE DEPOSITS

Glaciolacustrine deposits are present in the subsurface and to a very limited extent at the surface. Their extremely limited lateral extent precludes mapping them as a separate unit. Lake deposits consist of fine sands, silts, and clays which formed in lakes that were in front of, or on the glacier. The material was transported in suspension by meltwater and remained suspended until the meltwater reached an impoundment where the sediment settled in quiet water. This resulted in a uniform deposit of fine-grained sediments. Glacial lake deposits are yellow to yellow-brown when oxidized and gray when unoxidized.

A lake deposit unique to this area occurs in southwestern Hand County in 111N70W1B. This lake deposit, called the Ree Marl, is an extremely fossiliferous diatomite which contains abundant fish, turtle, gastropod and frog remains in a matrix composed almost entirely of microfossils. A great deal of work has been done on this deposit beginning with Cope (1891), who assigned an Oligocene age to the deposit. In the 1950's Morris Skinner assigned a Pleistocene age to the deposit (Uyeno and Miller, 1963). Ossian (1973) collected several hundred fossil fish and did a detailed paleontological study of the deposit. Based on these studies, the age of the deposit is Pleistocene and probably Wisconsin, although the exact age has not been determined.

LOESS

Eolian deposits associated with the late-Wisconsin glaciation consist of light-brown loess, which is composed primarily of silt-sized material with smaller amounts of clay and very fine sand. This material originated at or near the terminus of the ice sheet where sparse vegetation did little to protect the sediments from erosion. Prevailing winds scoured the fine-grained material and deposited it in a thin, relatively uniform layer near the ice front. The development of recent drainage systems has destroyed most of those deposits. The thickest deposit of loess observed in the two-County area is 7 feet but most deposits are 2 to 3 feet thick. Due to its patchy, discontinuous occurrence and relative thinness, this material was not mapped as a separate unit.

Holocene Deposits

Colluvium

Colluvium, a heterogeneous accumulation of weakly stratified clay, silt, sand and gravel, occurs on or at the base of slopes.

The largest of these deposits occur where the transition from the James Basin to the Coteau du Missouri is abrupt. This material was initially deposited by ice, but was later redeposited by slumps and mudflows in conjunction with periglacial processes such as frost wedging and solifluction which began soon after deposition. In the study area, colluvium occurs where the slope was steep enough for mass movement to occur, however, this unit is mapped only where it was of large lateral extent (pl. 3).

Alluvium

Alluvium is present in virtually all of the stream valleys in the two-County area. These deposits consist of dark-brown clays and silts with minor amounts of sand and gravel. They attain a maximum thickness of approximately 15 feet but are usually less than 10 feet thick. Alluvial sediments were deposited by intermittent streams when there was sufficient precipitation to allow runoff. Since no perennial streams exist in the study area, with the exception of the Missouri River, there has been little erosion or deposition since the glaciers receded. In many cases, the alluvium grades downward into outwash if a stream occupies a meltwater channel. This unit is often difficult to distinguish from fine-grained outwash and is mapped with outwash as an alluvium-outwash complex (pl. 3).

GLACIAL LANDFORMS

All of the landforms in the two-County area are a direct result of late Wisconsin glacial or glaciofluvial action. Little alteration of landforms has taken place since the retreat of the ice sheet. There are two primary reasons for this.

1. The relatively short time interval since deglaciation (approximately 10,000 years), and
2. the low erosion rates which are the result of the relatively dry climate and low topographic relief in most of the study area.

The general topography which existed prior to glaciation is still very much in evidence though it is greatly subdued. Topographic highs and lows which existed prior to glaciation maintain the same locations and relationships today, although more glacial drift accumulated in the low areas than at higher elevations reducing the preexisting topographic relief.

Stagnation Moraine

The most predominant landform in the two-County area is stagnation moraine (pl. 3). As used in this report, stagnation moraine is defined as glacial drift (primarily ablation till) which was deposited by stagnant (dead) ice. The moraine was formed when sediment in and on the ice was deposited as the ice melted. This type of moraine has few linear features with the exception of disintegration ridges and eskers, which will be discussed in a later section of this report.

Closed depressions are the most common and distinguished features on stagnation moraines (fig. 7). They were formed either by unequal thicknesses of ice or as kettles which result from the melting of ice blocks that were wholly or partially buried in the drift. Sediments collapse or slump into the position formerly occupied by the ice block leaving a depression on the surface. Flint (1955) referred to this type of landform as "collapsed topography."

The ice covering the study area was located near the limit of the ice sheet which covered North America (fig. 8). Because of this, the ice was relatively thin--less than 1,500 feet thick compared to 15,000 feet thick in central Canada (Hughes and others, 1981). Thus, the surficial features of the stagnation moraine are subdued and the relief is low.

Two types of stagnation moraines (high level and low level) were distinguished in the two-County area. Both were formed by the same processes, but they differ in elevation and in frequency and size of closed depressions.

High-level stagnation moraines were mapped on the Coteau du Missouri at elevations above 1,750 feet and were formed by ice that flowed over the preglacial topographic highs. This portion of the ice sheet was relatively thin because it was near the maximum extent of glaciation (fig. 8) and because the ice was flowing from a lower elevation (the ancient Ree Valley) to a higher elevation. This relatively thin glacier deposited a thinner layer of drift on the Coteau than on the lowlands. Fewer blocks of ice were buried in this drift resulting in fewer and larger closed depressions. The buried blocks of ice were as much as 1 mile wide forming closed depressions that are significantly larger than those on the low-level stagnation moraine. General bedrock features, such as topographic highs and lows, may be reflected in the surface.

Low-level stagnation moraines exist primarily in the Great Ree Valley (pl. 3) at elevations below 1,750 feet. Due to the low elevation of the preglacial surface, the ice sheet was thicker here than on the highlands and deposited greater thicknesses of drift which obscured features on the bedrock surface. Many small blocks of ice were buried in the drift forming numerous small closed depressions.

End Moraine

For the purpose of this report, end moraine is defined as a ridge-like accumulation of glacial drift which was deposited at

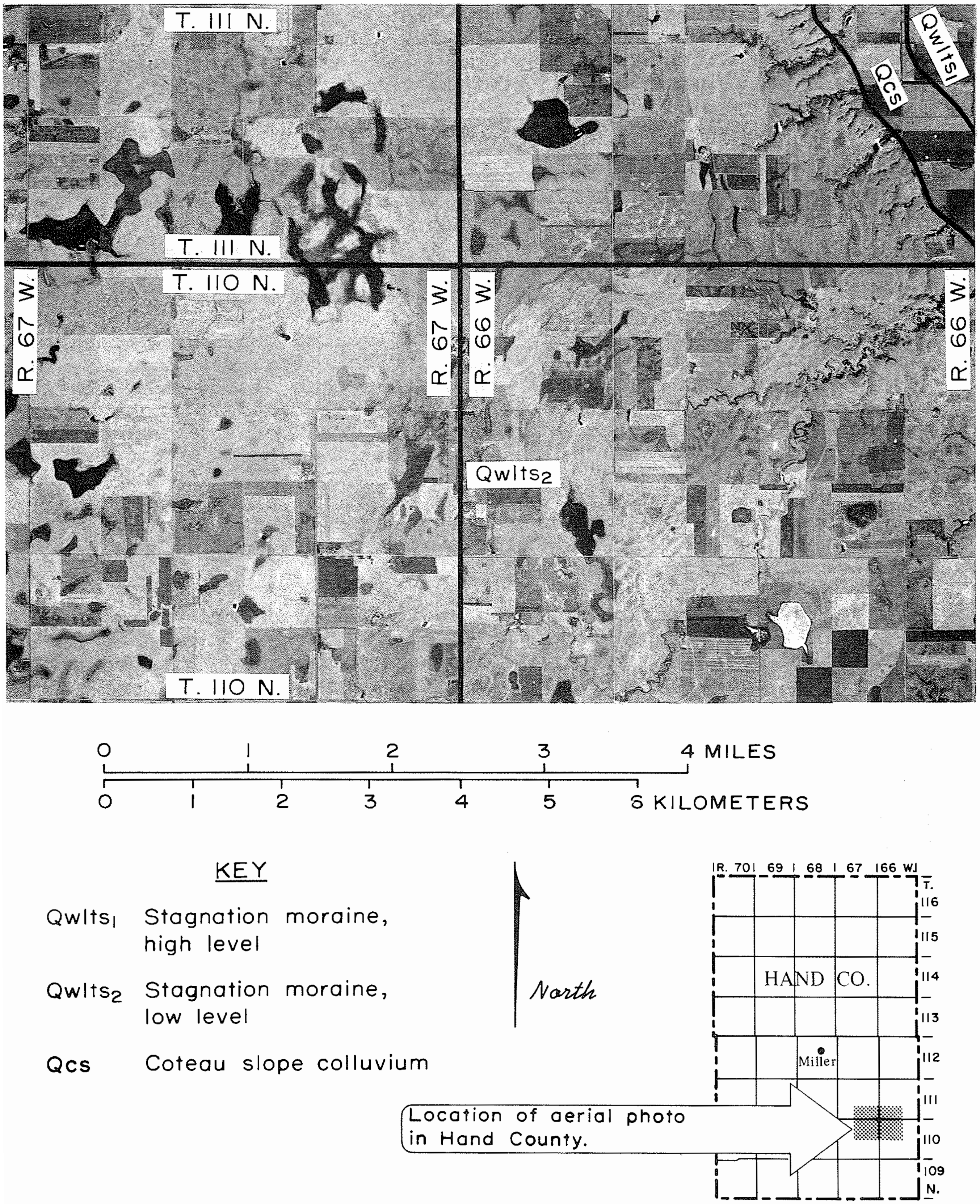


Figure 7. Aerial photograph of typical stagnation moraine.

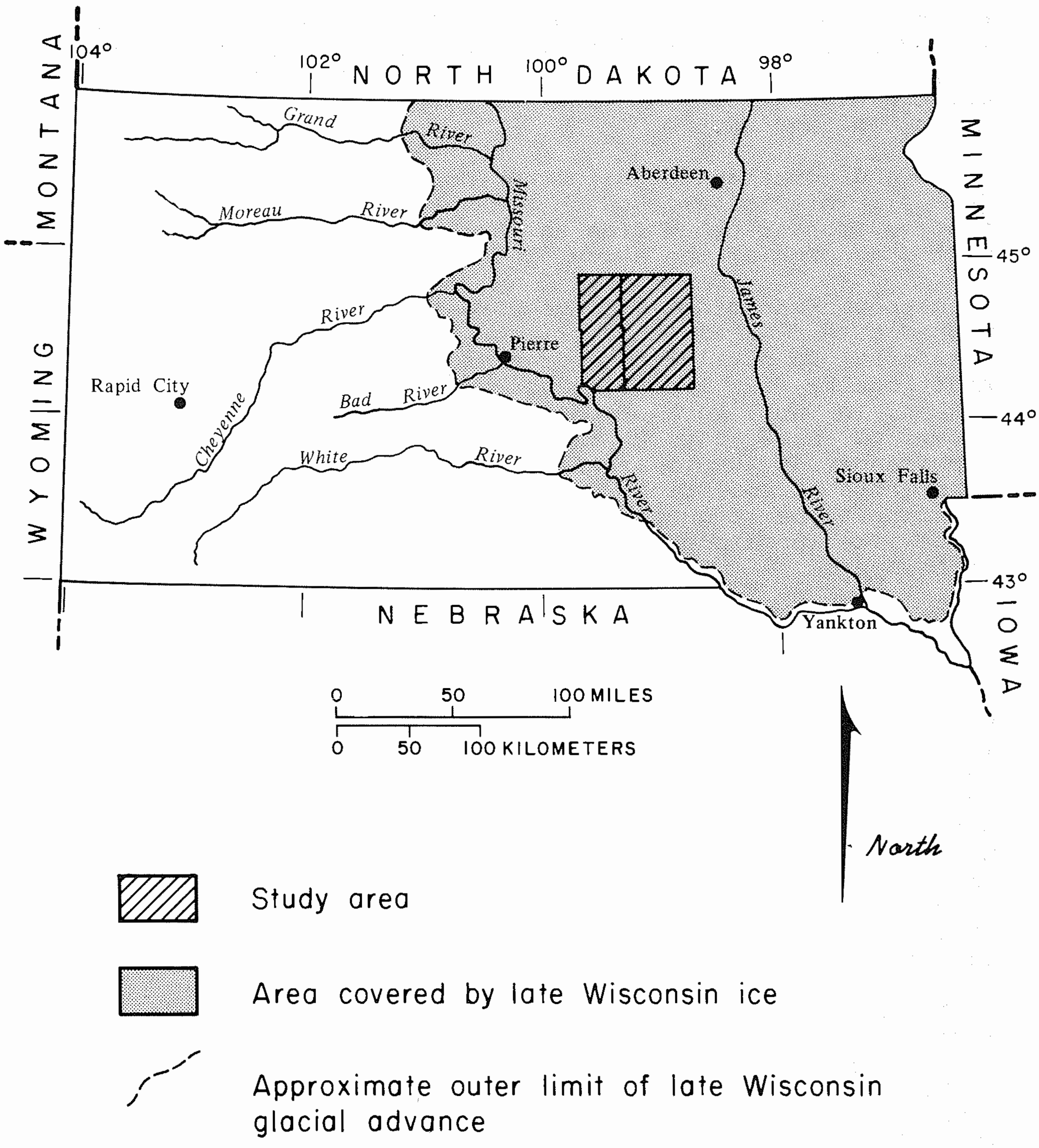


Figure 8. Limit of maximum ice advance for late Wisconsin in South Dakota. (from Lemke and others, 1965)

or near the terminus of an active glacier. Surface expression of an end moraine is typified by lineations (small and large scale) and, in many cases, abundant pot holes. Drainage is poorly developed except on the outer slopes or where intersection with a major drainage occurs.

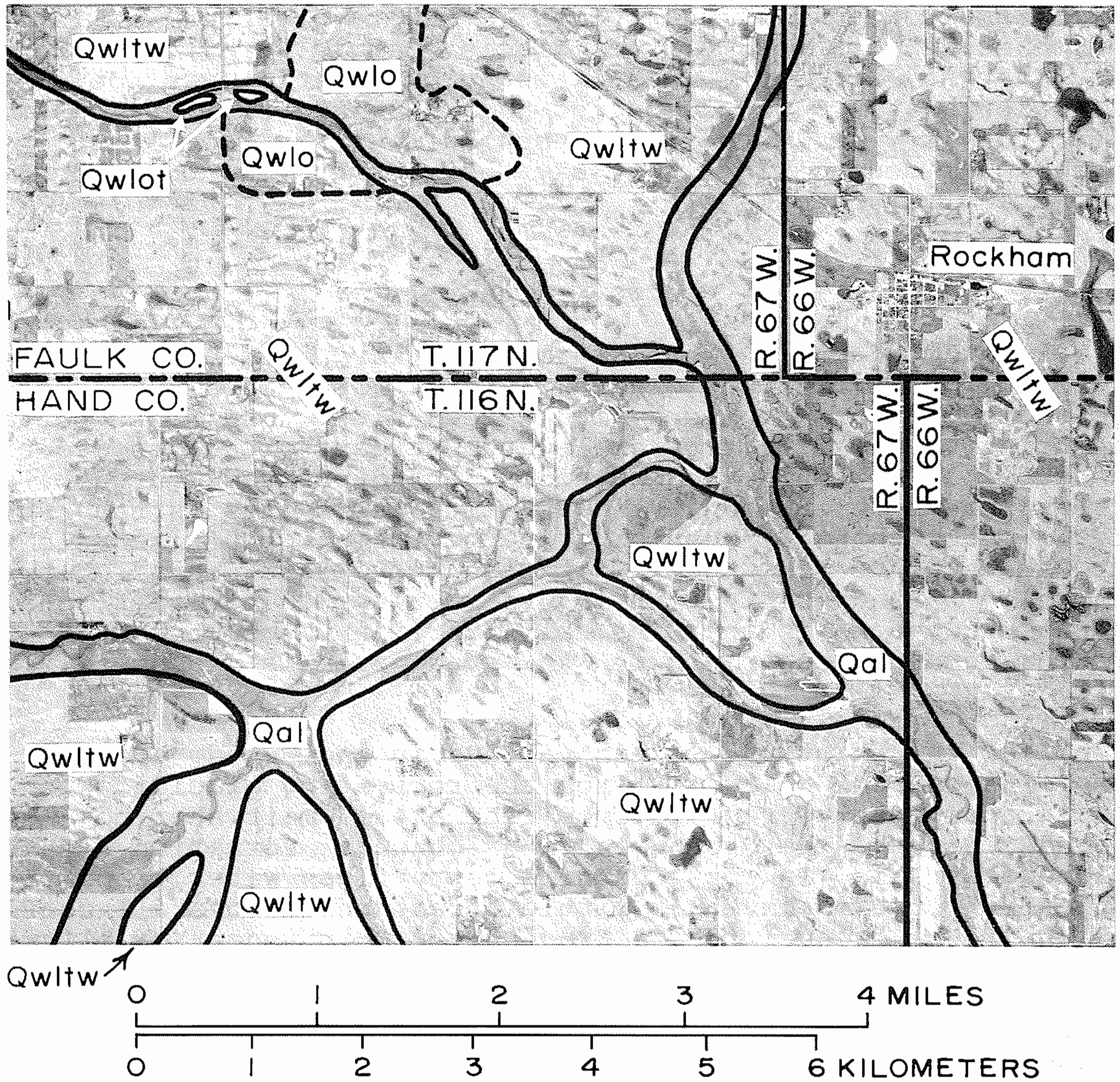
An end moraine occurs in the northern part of the study area (pl. 3). This is believed to be a recessional moraine formed as the ice front receded from the Bowdle end moraine, located to the west and north of the study area (Christensen, 1977).

Although the sides of the Great Ree Valley were previously mapped as end moraine by Flint (1955), drill holes in parts of this area did not indicate greater than normal drift thicknesses. Additionally, few linear ridges were noted on the aerial photographs. In fact, much of this area mapped as end moraine by Flint proved to have a very thin drift cover, and the ridge-like appearance was due to a reflection of the bedrock surface through thin drift accumulations on preexisting valley sides. These areas are mapped as stagnation moraine or coteau slope because the ridge-like appearance was inherited from the preexisting bedrock topography.

Washboard Moraine

A large area of northeastern Hand County consists of washboard moraines (pl. 3). The name originates from a pattern of small linear ridges which can be seen when viewed from the air or with the aid of aerial photographs but are difficult to see from the ground. When viewed from the air, hundreds of small, curvilinear, sub-parallel ridges are apparent (fig. 9), ranging in length from tens of feet to over one-half mile and characteristically 5 feet or less in height. The ridges "are transverse to the glacier flow direction and sub-parallel to the glacier margin" (Kemmis and others, 1981, p. 52). They are also called corrugated or minor moraines.

There are many postulated modes of formation for washboard moraines which are summarized in Kemmis and others (1981). Gwynne (1951) mapped "minor" moraines adjacent to the James River Valley in South Dakota, and proposed that they were formed by seasonal advance and retreat of the ice margin as the ice sheet receded from the area. Active ice sheared over small blocks of stagnant ice near the margin depositing lodgement till in small ridges. Most of the other modes of formation involve ice shearing or thrust plains in the ice, but a few are more diverse and include annual push moraines and the squeezing of subglacial debris up into ice crevasses (Kemmis and others, 1981). Based on the regularity and parallel nature of the ridges in the study area, Gwynne's (1951) origin appears to be the most likely manner of formation in Hand County.



KEY

Qal	Alluvium
Qwlo	Outwash
Qwlot	Outwash terrace
Qwltw	Washboard moraine

North

Faulk County geology from Christensen (1977).

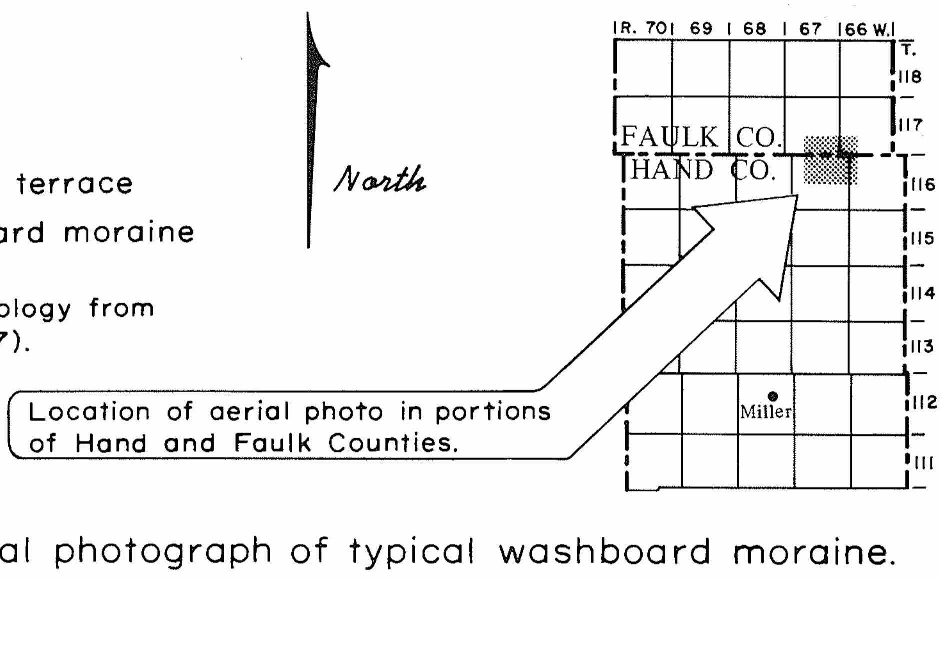


Figure 9. Aerial photograph of typical washboard moraine.

The small height of the ridges is due to a variety of factors. The seasonal advances of the glacier margin were not large or long lasting, so only a small amount of material was deposited. The material that was deposited had a relatively fine particle size, so it was more easily spread out by solifluction or postglacial degradation that may have destroyed the ridges in some areas (Gwynne, 1951).

Meltwater Channels

Meltwater channels were formed by large amounts of water flowing away from the glaciers as it stagnated or receded. Typically they are valleys with steep sides and flat bottoms. Depending on the flow rate, meltwater streams either eroded into the surface forming the channels or deposited outwash. The streams had both erosional and depositional cycles as the volume of the water changed, resulting in the formation of channels with outwash deposits in them. Although there are more meltwater channels in Hand County than in Hyde County, the largest channel in the study area is the Missouri River, in the southwest corner of Hyde County. Its origin in the study area is discussed later in the text.

All of the existing stream valleys in the study area at one time carried some meltwater from the retreating glacier. When the glacier completely receded from the area, meltwater no longer flowed through the channels and channel formation ceased. Holocene streams in the channels carry less water, and these "underfit" streams have had little effect on the overall configuration of the channel, depositing only a thin veneer of alluvium. This has been mapped as alluvium-outwash complex (pl. 3). Generally, the larger channels contain a greater thickness of alluvium and outwash, while the upper reaches of many of the meltwater channels contain little or no outwash or recent alluvium. A few channels were completely abandoned after the glacier receded and no alluvium was deposited in them.

Two major types of meltwater channels are present in the study area: those which are roughly parallel to the ice front and those which are roughly perpendicular to the ice front. Ice-marginal channels are roughly parallel to the retreating ice front and are found primarily in Hand County. They formed as the ice sheet retreated and meltwater flowed to the southeast between the ice front and the Coteau du Missouri escarpment. Portions of the valleys of Pearl, Turtle, Wolf, and Medicine Creeks were formed in this manner (fig. 3). Meltwater flowing away from the ice front formed channels that have thicker outwash deposits in their upper reaches than in the downstream portions of their channels. These deposits formed as sediment-laden meltwater deposited coarse material near the ice front and transported fine material away from the glacier. This is evidenced by approximately 100 feet of outwash in the valley of South Fork of Medicine Knoll Creek near Highmore, and only 30 feet of outwash in the same creek valley near Harrold (Hughes County). Two other examples of meltwater channels of this second type are the valleys of Elm Creek and the North Fork of Medicine Knoll Creek (fig. 3).

Outwash Terraces

Outwash terraces associated with the previously described meltwater channels are remnants of former flood plains which were abandoned after the stream had been entrenched. These deposits are quite small in areal extent and occur on the sides of larger meltwater channels. Composed of clay- to gravel-sized outwash, these terraces have gently sloping to flat surfaces. Terraces of this type provide much of the sand and gravel which is extracted for economic use in the area.

Ice-Disintegration Features

Disintegration ridges and eskers are two additional types of linear features found in the study area. Disintegration ridges are found in most of the stagnation moraines in the two-County area, however, only the most pronounced were mapped (pl. 3). These ridges are believed to have been the result of superglacial and englacial drift accumulating as fillings in crevasses or other openings in the ice sheet. As the ice melted, this material retained the approximate shape of the opening in which it was contained. These include boxwork configurations (primarily crevasse fillings) and circular, doughnut-like shapes, which were formed in holes in the ice.

Eskers are sinuous ridges composed of sand and gravel with minor amounts of silt or clay that were deposited by meltwater streams flowing under the ice. Meltwater flowing in crevasses or other openings in the glacier eroded tunnels within or beneath the ice. As these tunnels carried the meltwater toward the terminus of the glacier, the coarser fraction of the sediment load was deposited in the tunnels. Remnants of these water-laid deposits form ridges after the ice melts. Eskers are relatively uncommon in this portion of the State and only one was found in the study area (pl. 3, 110N69W25 to 110N69W35).

NONGLACIAL LANDFORMS

Stream Eroded Bedrock Topography

Stream eroded bedrock topography is confined to a small area in southwestern Hyde County. Clayton (1962) used this term to describe areas that had been glaciated but from which subsequent erosion had removed much or all of the glacial deposits leaving bedrock exposed at the surface. After the Missouri River formed, downcutting by the river lowered the local base level prompting headward erosion in its tributaries. This caused the removal of essentially all of the glacial materials from the Missouri River Valley and the creation of high local relief. Maximum relief from water level in the Missouri River to the top of the valley is approximately 700 feet. On the steep slopes of the valley sides there has been a great deal of slumping in the Pierre Shale.

Coteau Slope

Coteau slope consists of colluvium and contains many features common to stagnation moraine. It was mapped where there is an abrupt change in slope on the boundary between the James Basin and the Coteau du Missouri. Linear features are not uncommon and are due to the reflection of the underlying bedrock rather than to the constructional activity of the glacier. This deposition resulted in a broad apron of material which tends to smooth the transition from the James Basin to the Coteau du Missouri and also marks the separation between the high and low level stagnation moraine where present. Two areas were mapped as Coteau slope, one west of Miller and the other south of Vayland (pl. 3).

GEOLOGIC HISTORY

Pre-Pleistocene

Approximately 480 million years ago, during the Ordovician period, the Williston Basin began to form with sediments accumulating in it (Carlson and Anderson, 1965). The southeastern most extension of this basin underlies the study area (fig. 5). Many episodes of deposition and erosion (or nondeposition) occurred throughout the remainder of the Paleozoic and the first half of the Mesozoic eras. The Cretaceous period was predominantly a period of deposition in the study area. During this time the entire study area was covered with over 2,000 feet of sediment deposited in inland seas (table 1).

Deposition continued into the early Tertiary period, but there are no Tertiary rocks now present in the two-County area. Erosional remnants of Tertiary rocks at Wessington Springs (Jerauld County) and west of the Missouri River near Reliance (Lyman County) suggest that Tertiary deposits once covered the study area. After the epeirogenic uplift during the last half of the Tertiary period, the area was exposed to subaerial erosion. During this period of erosion the preglacial drainage network was initiated and large quantities of previously deposited sediments were removed.

Pleistocene

Pre-Late Wisconsin

Erosion continued throughout the Pleistocene until the late-

Wisconsin age began. As a result of this erosion, Hand and Hyde Counties, prior to glaciation, were topographically very similar to the area presently found west of the Missouri River. Rolling hills dissected by a well integrated drainage network typified the area. Alluvial sediments were deposited in stream valleys and isolated buttes capped with Tertiary sediments probably existed; however, Pierre Shale was the predominant surficial material. The Niobrara Formation was the only other bedrock unit exposed in the study area. These exposures appeared in deep stream valleys near Miller and in the extreme northeastern part of Hand County as the drainages had cut into the Niobrara Formation prior to glaciation.

The drainage network that existed prior to glaciation can be estimated using the bedrock topographic map (pl. 2). The reader is cautioned not to use plate 1 as an exact paleo-topographic map because it portrays the bedrock surface after modification by the late Wisconsin ice sheet. Although local relief on the bedrock surface varies from less than 2 feet per mile (114N68W) to approximately 380 feet per mile (112N66W31), the general slope of the study are is towards the ancient Ree Valley at approximately 36 feet per mile. The valley itself slopes to the east at approximately 8 feet per mile.

Plate 1 and figure 10 illustrate the major drainages that existed in Hand and Hyde Counties prior to glaciation. Flint (1955) suspected the presence of these preglacial extensions of the present western drainages, and test drilling completed for this study provided the required proof of their existence. The most prominent channel enters western Hyde County in 113N73W and traverses the study area in a west to east direction. A tributary from the northwest joins this channel in northwest Hand County. Based on test drilling for the Hughes County Study (Duchossois, in preparation), the channel is correlated with the present Bad River (fig. 11). Hedges and others (1982) and Koch (1980) proposed that the ancient Cheyenne River joined the ancient Bad River in western Hyde County, but test drilling in Sully County proved this to be incorrect. Duchossois (1985) proposed that the ancient Cheyenne River flowed through Potter County and joined the ancient Grand River in Faulk County (fig. 11). Further test drilling in Potter County will be necessary to verify this hypothesis.

A channel which enters Hand County from Faulk County in 116N67W05 is the preglacial extension of the present Grand River (figs. 10 and 11). Christensen (1977) has delineated the location of this channel quite thoroughly north of the study area. Only a small segment of this major channel is present in Hand County, as it leaves the County in 115N66W25. This is also where the ancient Bad River joined the ancient Grand River. From there the ancient Grand River flowed east to northern Beadle County where it changed direction to flow north into North Dakota (fig. 11). Eventually it drained into Hudson Bay. It was this drainage network and its associated interfluves which greatly influenced

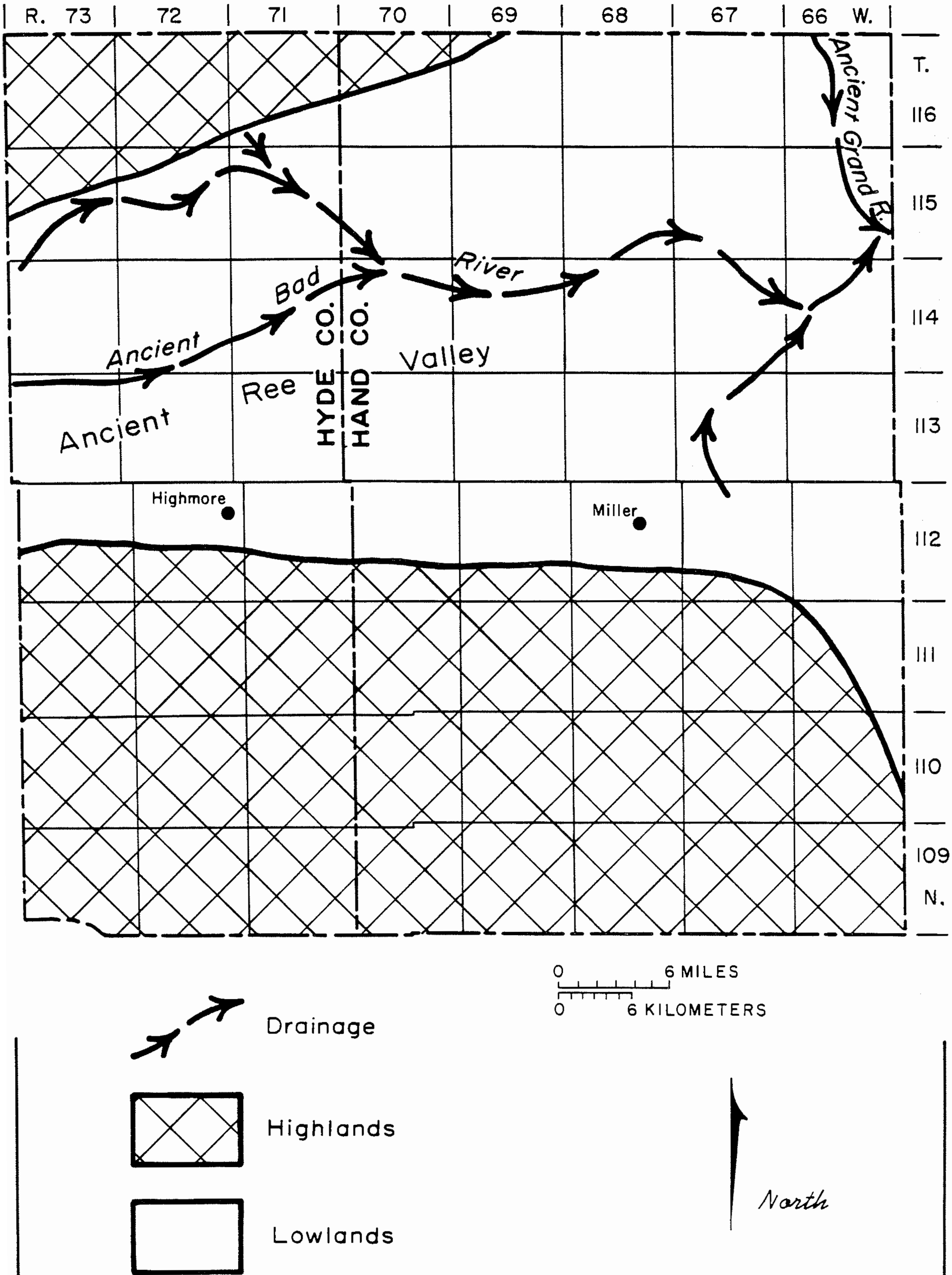


Figure 10. Drainage and generalized topography prior to glaciation in Hand and Hyde Counties.

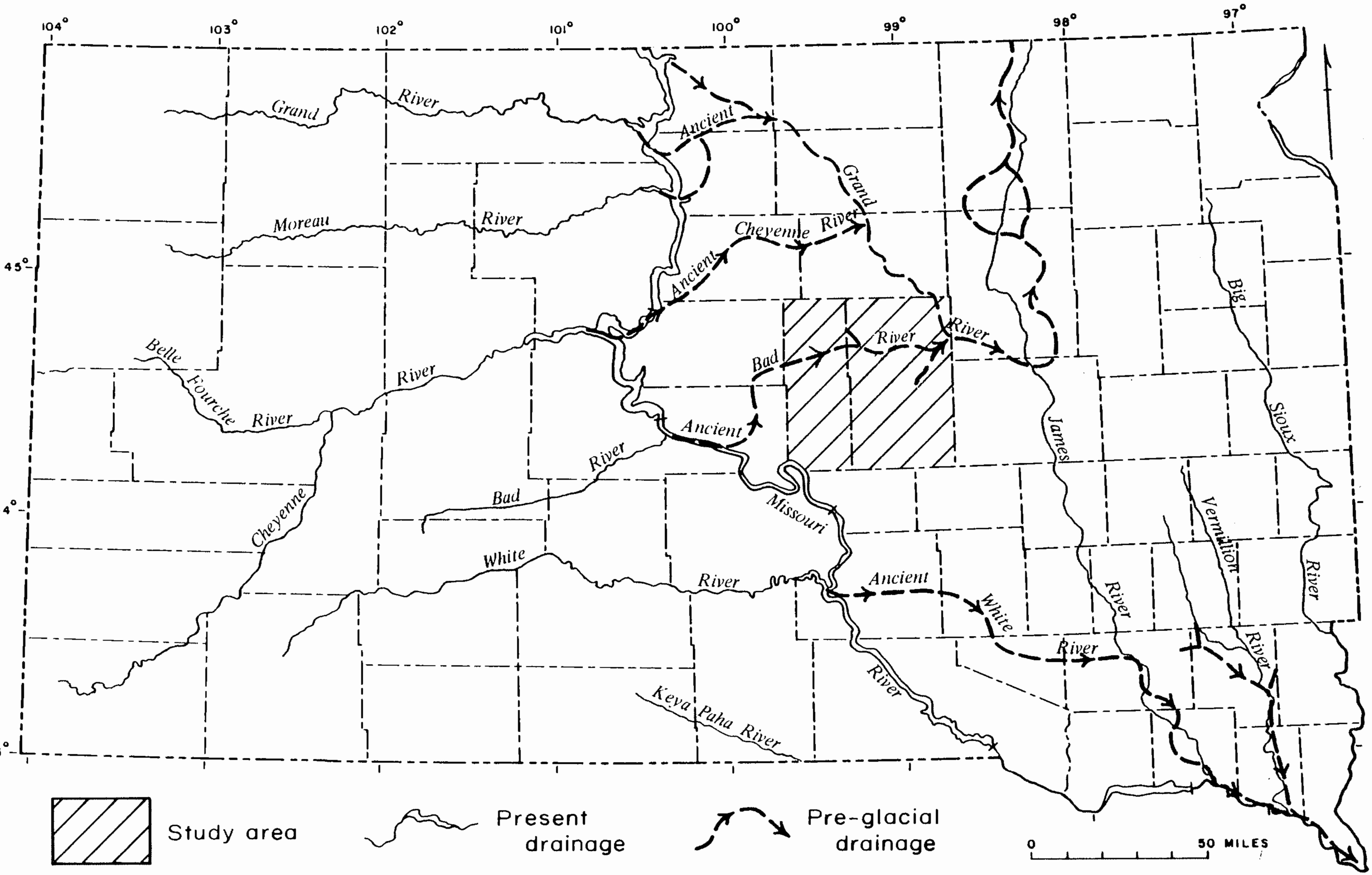


Figure 11. Inferred pre-glacial drainage in eastern South Dakota (modified from Duchossois, 1985; and Hedges and others, 1982).

ice movement and the formation of the present topography of the two-County area.

Late Wisconsin

As stated previously, the surficial geology and geomorphology of the two-County area is primarily the result of the late-Wisconsin glaciation. Direction of movement of the ice and the resulting topography was influenced by the preglacial topography which provided the foundation on which the ice sheet moved. The ancient Bad River system and its associated interfluves were the major topographic features in the area and had the greatest effect on ice movement. Two factors are responsible for the large degree of influence exerted by the preexisting topography.

1. There was only one major ice advance in the area, and
2. the study area is located near the limit of glaciation resulting in relatively thin ice and thin drift deposits.

In much of South Dakota east of the study area multiple glaciations with thick accumulations of drift have obscured the pre-Pleistocene topography almost entirely.

Ice first entered the James Basin from the north, flowing south in the ancient Grand River Valley in Brown, Spink, and Beadle Counties. This ice mass (termed the James Lobe) was confined on the east by the Coteau des Prairies and on the west by the Coteau du Missouri. A sublobe flowed into Hand County through the ancient Ree Valley moving essentially perpendicular to the flow of the major ice sheet. Initially the movement of ice into the study area was confined to the low area of the ancient Ree Valley. Flowing up the preexisting valley, the sublobe smoothed the topography, dammed the river and widened the valley forming the Great Ree Valley. This valley today forms an embayment or topographic breach in the Coteau du Missouri.

During the early stages of glaciation in the study area, ice dammed the ancient Bad River. Water was ponded in a temporary lake which existed until a sufficient quantity of water had accumulated to overtop the drainage divide to the south. Once this divide was breached, a meltwater channel was cut parallel to the ice front (fig. 12). Large quantities of meltwater were carried by this channel for a short time, as evidenced by the fact that it was incised 400 feet into the Pierre Shale (pl. 1). A test hole located over this channel (110N66W96BBBB) encountered 73 feet of coarse glacial outwash overlying the Pierre Shale. The advancing ice sheet deposited drift on top of the outwash as it flowed up the ancient Ree Valley and overtopped the Coteau du Missouri in Hand County.

The ice advanced steadily from the north and east, eventually covering all of Hand and Hyde Counties as well as areas further

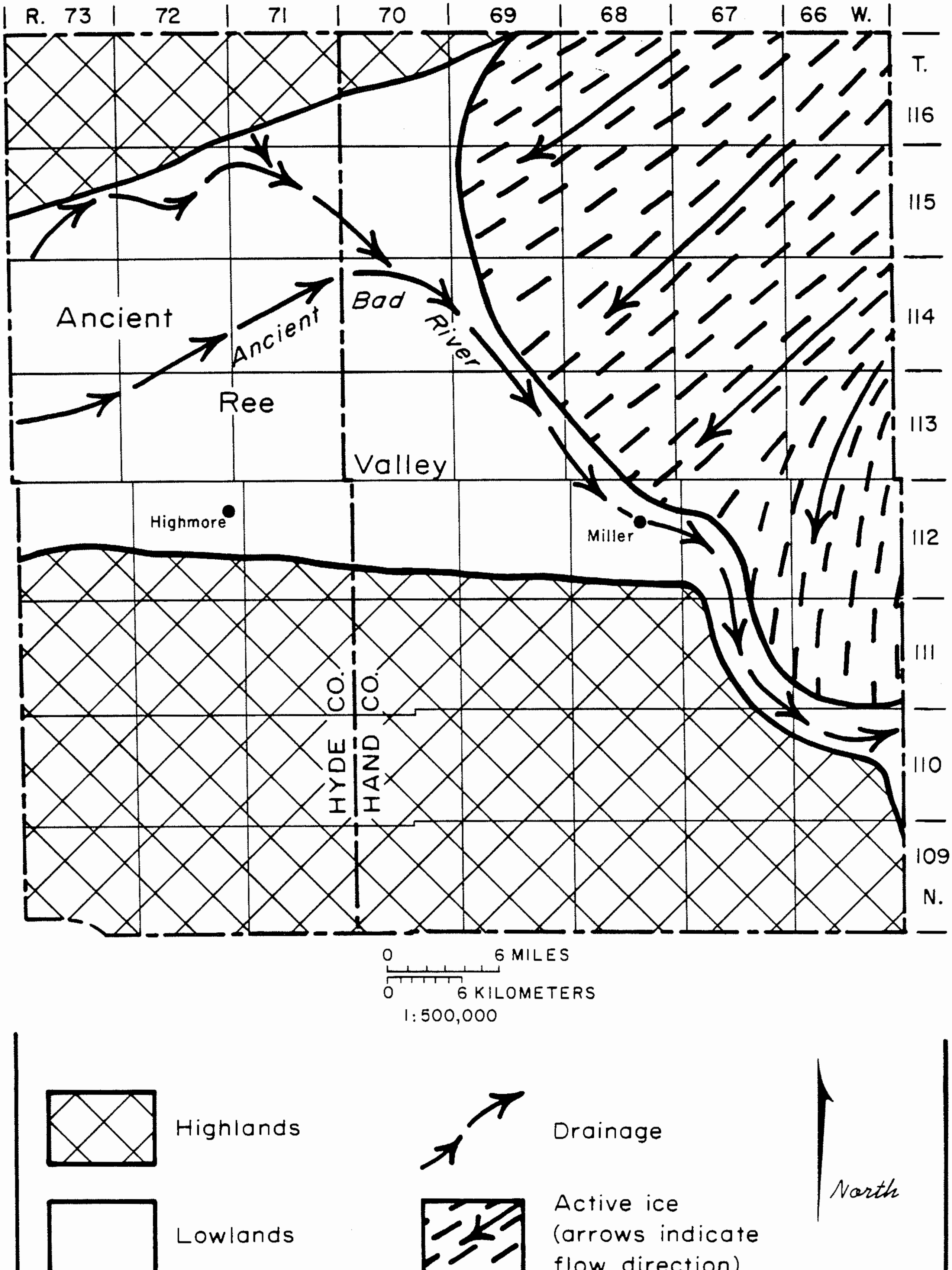


Figure 12. Ice advance in study area and inferred direction of drainage.

west (fig. 8). Undoubtedly, there were several minor retreats and advances of the ice sheet as it expanded from east to west across Hand and Hyde Counties, but evidence of these minor events has been obliterated by subsequent movement of the ice. As a result, landforms which currently occupy the two-County area were formed primarily by the retreating ice sheet. Once the ice sheet reached its maximum position (fig. 8) and started to recede, the landforms present in the Counties today began to emerge.

The present course of the Missouri River in central South Dakota was established while the ice was at or near its maximum. The river flowed along the ice front carrying meltwater from the ice sheet was well as surficial drainage from the west. Ice that advanced west of the present Missouri River was very thin and probably flowed over the Missouri River Valley without diverting the river. As more meltwater was carried away from the ice sheet by the Missouri River, the river became deeply incised in its present location. The newly formed river became the major drainage in the State which would carry meltwater from the retreating ice front.

During the initial stages of recession, a large portion of the ice stagnated west of the present drainage divide separating the Missouri River from the James River (fig. 13). Ice in the Great Ree Valley remained active and was fed by the James Lobe to the east. Meltwater from the stagnant ice flowed into the Missouri River during this stage of the recession, depositing outwash and forming meltwater channels which are currently occupied by the North and South Forks of Medicine Knoll Creek and Chapelle Creek.

After further retreat of the ice, some of the meltwater could no longer reach the Missouri River via the above-mentioned streams because the ice had retreated eastward beyond the present James-Missouri drainage divide. A proglacial lake was formed as water impounded in the Elm Creek area and the Ree Marl was deposited (fig. 14). Once the quantity of meltwater was sufficient to overtop the drainage divide in west-central Hand County, Elm Creek began to form and the lake was gradually drained as the outlet was lowered by erosion. In the process much of the lake deposit was eroded so that only a small remnant of the lake sediments remains. The stream began to aggrade as the flow gradually decreased, and up to 36 feet of outwash was deposited in the Elm Creek Valley. It was at approximately this same time that the Wall Lake-Spring Lake meltwater channel was formed in a similar manner.

As the active ice front retreated further east, meltwater began to flow east and south between the highlands of the Coteau du Missouri and the active ice margin (fig. 15). After further recession, more ice marginal meltwater channels formed which also drained the stagnant ice (fig. 16). As ice melted, slumping occurred along the eastern slope of the Coteau du Missouri forming colluvium deposits. Ultimately the ice retreated to the

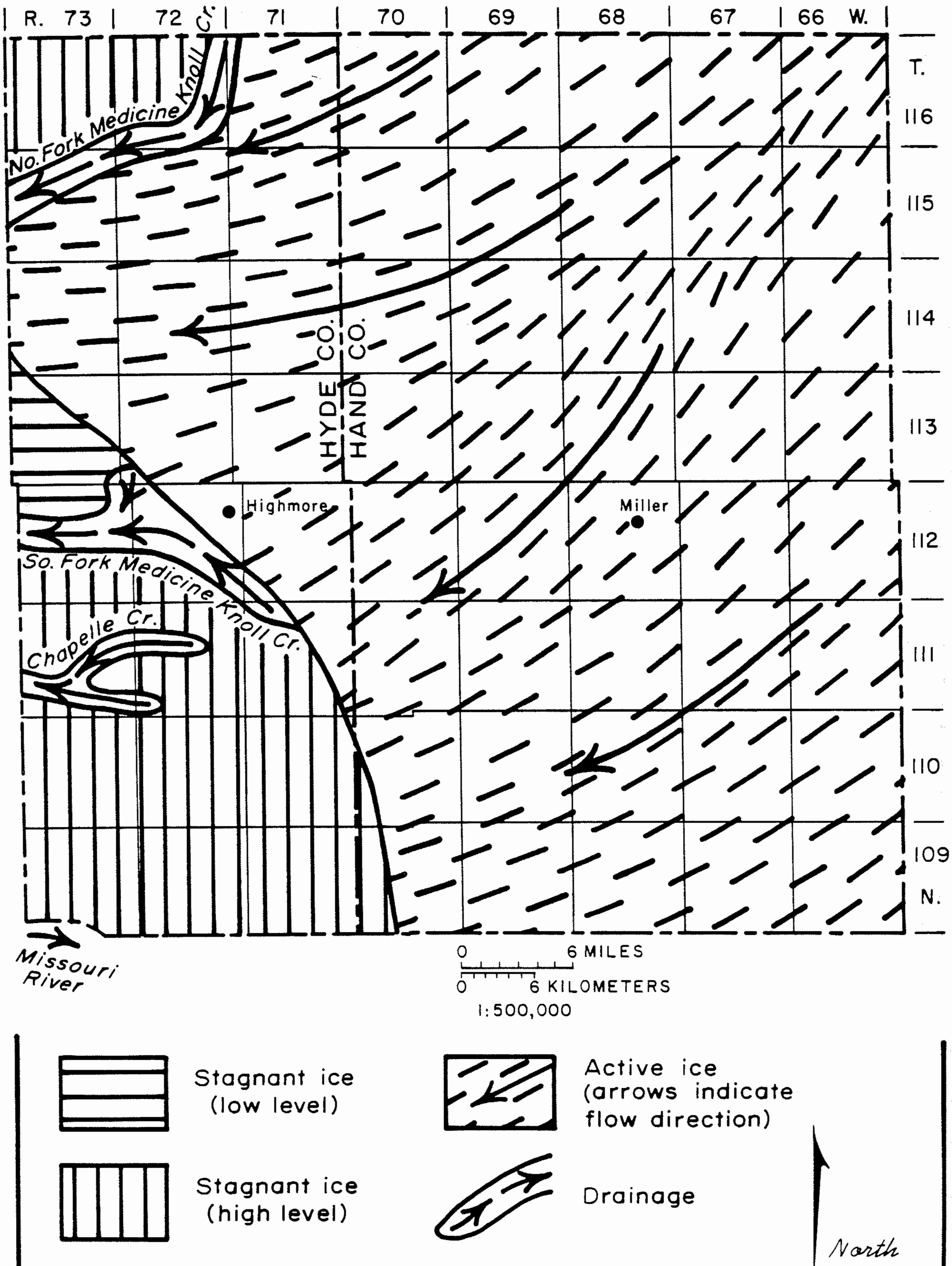


Figure 13. Initial stage of ice retreat in study area.

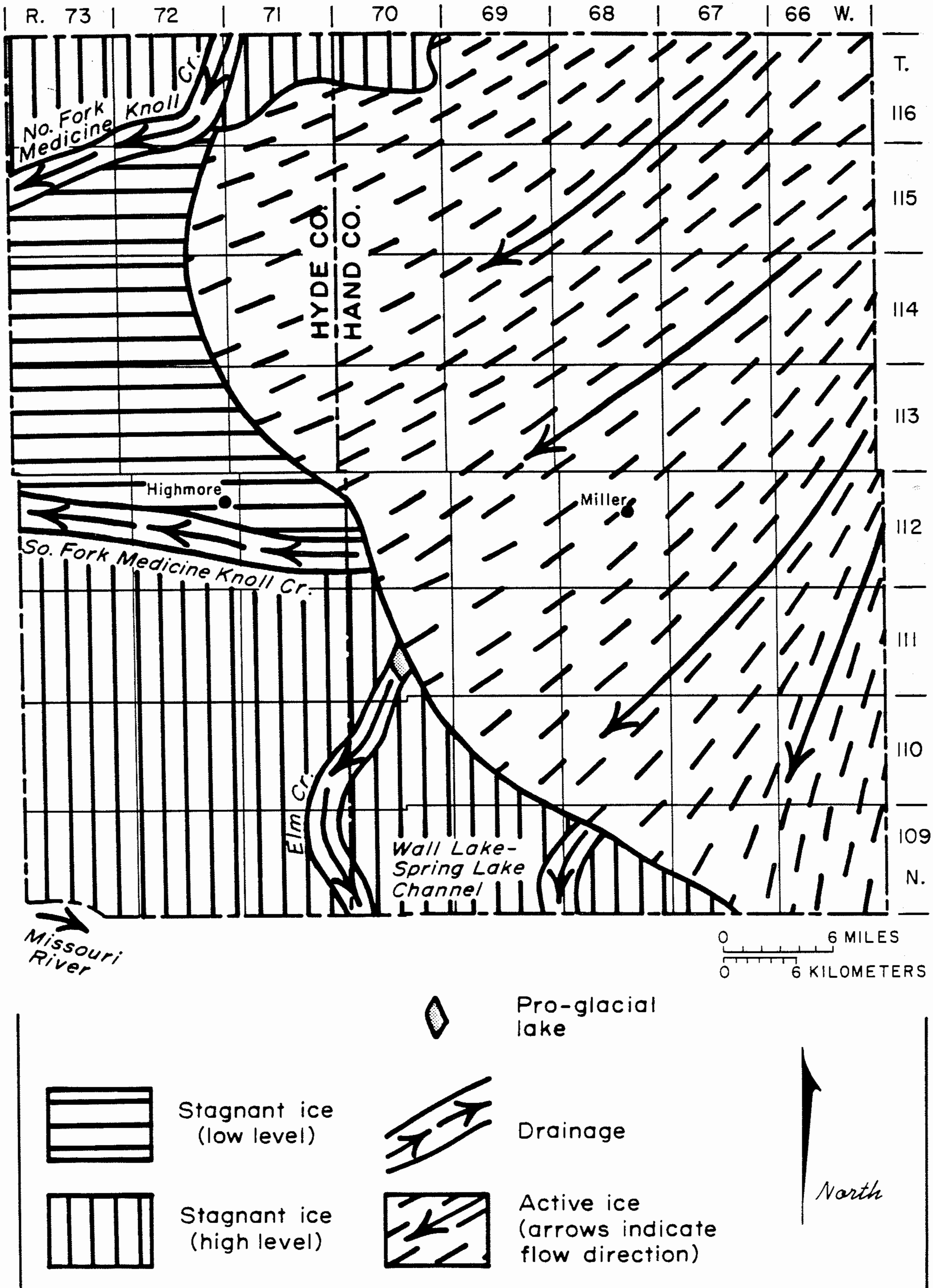


Figure 14. Second stage of ice retreat in study area.

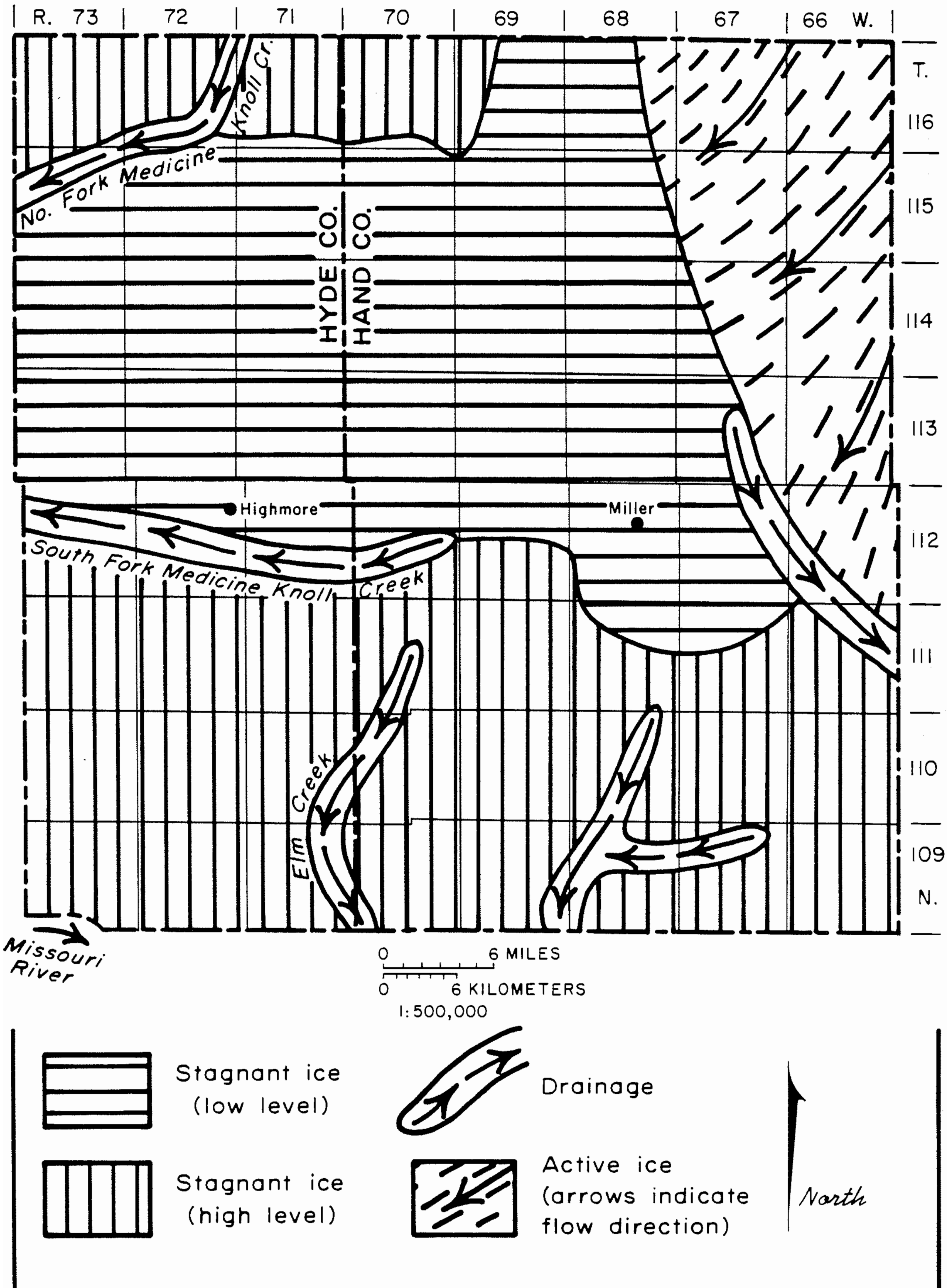


Figure 15. Third stage of ice retreat in study area.

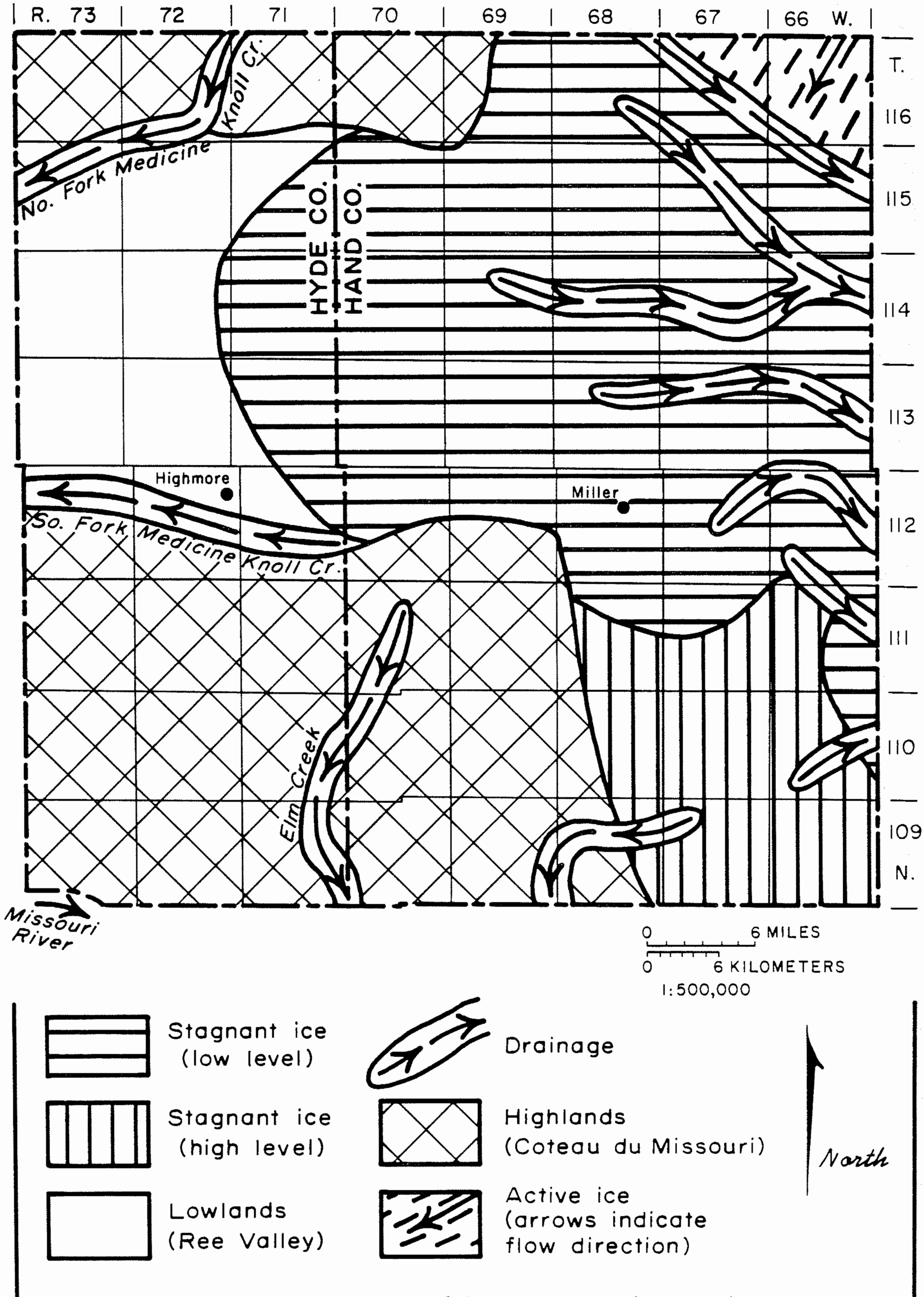


Figure 16. Fourth stage of ice retreat in study area.

north and east out of the James Basin, and meltwater continued to flow south and east, coalescing in the James River.

In summary, glacial action smoothed the preglacial topography by gently eroding high areas and filling in low areas. Other major effects of glaciation were to widen the ancient Ree Valley, especially in eastern Hand County, and to divert the flow of the ancient Bad River into what is now the Missouri River.

Holocene

In general, there has been little change in the landscape or drainage in the two-County area since the glaciers receded. Erosion rates decreased due to the absence of glacial meltwater and low precipitation, but minor amounts of alluvium were deposited in stream valleys.

ECONOMIC GEOLOGY

Water Resources

The most important economic resource found in Hand and Hyde Counties is water. However, this resource is not distributed evenly throughout the two Counties, and as a result it is difficult and expensive to obtain a high-quality water supply in some areas. A detailed discussion of surface- and ground-water resources can be found in Part II of this report (Koch, 1980). A less detailed, nontechnical report is also available which discusses the location of the major aquifers and the quality of the water (Koch, 1976).

Sand and Gravel

Another major economic resource found in Hand and Hyde Counties is sand and gravel. As in the case of water, this resource is not evenly distributed throughout the area nor is the quality consistent. A more detailed publication dealing with the distribution of sand and gravel has been prepared for each County (Schroeder, 1976a, and 1976b). Concentrations of boulder-sized glacial erratics may provide a very limited source of riprap.

Other Mineral Resources

There is currently no oil or gas production in the two-County area, however, several exploratory holes have been drilled.

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APPENDIX

Logs of test holes cited

COUNTY: **Hand** LOCATION: **110N-66W-06BBBB**
LEGAL LOCATION: **NW NW NW NW sec. 06, T. 110 N., R. 66 W.**
LATITUDE: **44.2213** LONGITUDE: **98.4924**
LAND OWNER:
PROJECT: **Hand County Study**
DRILLING COMPANY: **SDGS**
DRILLER: DRILLER'S LOG:
GEOLOGIST: **R. Helgerson** GEOLOGIST'S LOG: **X**
DATE DRILLED: **08-02-1973** DRILLING METHOD: **Rotary**
GROUND-SURFACE ELEVATION: **1815.00 T**
TOTAL DRILL HOLE DEPTH: **530** TEST-HOLE NUMBER: **R-11**
USGS HYDROLOGICAL UNIT CODE: **10160006**
ELECTRIC LOG INFORMATION:
SPONTANEOUS POTENTIAL: **X** SINGLE POINT RESISTIVITY: **X**
NATURAL GAMMA: EXTRA:
SAMPLES:

0 - 1	Topsoil, black
1 - 18	Clay, yellow-brown, silty (till)
18 - 31	Clay, gray, silty (till)
31 - 109	Clay, gray, silty, gravelly; with gravel stringers (till)
109 - 124	Sand and gravel; clay stringers from 119 to 121 feet
124 - 346	Clay, gray, silty, pebbly; shaley (till)
346 - 352	Gravel
352 - 427	Clay, gray, gravelly; shaley, with gravel stringers (till)
427 - 500	Gravel, coarse; granite, quartzite, coal and limestone
500 - 530	Pierre Shale

* * * *

COUNTY: **Hand** LOCATION: **112N-67W-03BBBB**
LEGAL LOCATION: **NW NW NW NW sec. 03, T. 112 N., R. 67 W.**
LATITUDE: **44.3251** LONGITUDE: **98.5259**
LAND OWNER:
PROJECT: **Hand County Study**
DRILLING COMPANY: **SDGS**
DRILLER: DRILLER'S LOG:
GEOLOGIST: **R. Helgerson** GEOLOGIST'S LOG: **X**
DATE DRILLED: **05-18-1976** DRILLING METHOD: **Rotary**
GROUND-SURFACE ELEVATION: **1468.00 T**
TOTAL DRILL HOLE DEPTH: **470** TEST-HOLE NUMBER: **R-185**
USGS HYDROLOGICAL UNIT CODE: **10160009**
ELECTRIC LOG INFORMATION:
SPONTANEOUS POTENTIAL: SINGLE POINT RESISTIVITY: **X**
NATURAL GAMMA: **X** EXTRA:
SAMPLES:

0 - 3	Topsoil, gray
3 - 8	Clay, gray, silty (till)
8 - 18	Clay, yellow, silty (till)

18 - 145	Clay, gray, silty, pebbly; sand and gravel stringers (till)
145 - 335	Clay, gray, silty, pebbly (till)
335 - 422	Clay, gray, silty, pebbly (till)
422 - 440	Gravel
440 - 470	Niobrara Formation

* * * *

COUNTY: **Hand** LOCATION: **112N-67W-10BBBB**
LEGAL LOCATION: **NW NW NW NW sec. 10, T. 112 N., R. 67 W.**
LATITUDE: **44.3146** LONGITUDE: **98.5259**
LAND OWNER:
PROJECT: **Hand County Study**
DRILLING COMPANY: **SDGS**
DRILLER: DRILLER'S LOG:
GEOLOGIST: **R. Helgerson** GEOLOGIST'S LOG: **X**
DATE DRILLED: **05-13-1976** DRILLING METHOD: **Rotary**
GROUND-SURFACE ELEVATION: **1485.00 T**
TOTAL DRILL HOLE DEPTH: **425** TEST-HOLE NUMBER: **R-180**
USGS HYDROLOGICAL UNIT CODE: **10160006**
ELECTRIC LOG INFORMATION:
SPONTANEOUS POTENTIAL: SINGLE POINT RESISTIVITY: **X**
NATURAL GAMMA: **X** EXTRA:
SAMPLES:

0 - 3	Topsoil, black
3 - 16	Clay, yellow-brown, pebbly (till)
16 - 53	Clay, gray, pebbly (till)
53 - 59	Sand
59 - 104	Clay, gray, silty, pebbly (till)
104 - 106	Gravel
106 - 112	Clay, gray, silty, pebbly (till)
112 - 114	Gravel
114 - 119	Clay, gray, silty, pebbly (till)
119 - 142	Gravel; with abundant clay stringers
142 - 198	Clay, gray, with abundant shale pebbles (till)
198 - 201	Gravel
201 - 322	Clay, gray, silty, pebbly (till)
322 - 327	Sand and gravel
327 - 346	Clay, gray, silty, very sandy (till)
346 - 349	Gravel
349 - 366	Clay, gray, silty, very sandy (till)
366 - 370	Sand and gravel
370 - 410	Clay, gray, silty, sandy (till)
410 - 425	Niobrara Formation

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COUNTY: **Hand** LOCATION: **116N-66W-21BBBB**
LEGAL LOCATION: **NW NW NW NW sec. 21, T. 116 N., R. 66 W.**
LATITUDE: **44.5107** LONGITUDE: **98.4710**
LAND OWNER:
PROJECT: **Hand County Study**

DRILLING COMPANY: **SDGS**
DRILLER: DRILLER'S LOG:
GEOLOGIST: **R. Helgerson** GEOLOGIST'S LOG: **X**
DATE DRILLED: **05-20-1976** DRILLING METHOD: **Rotary**
GROUND-SURFACE ELEVATION: **1366.00 T**
TOTAL DRILL HOLE DEPTH: **335** TEST-HOLE NUMBER: **R-190**
USGS HYDROLOGICAL UNIT CODE: **10160009**
ELECTRIC LOG INFORMATION:
SPONTANEOUS POTENTIAL: SINGLE POINT RESISTIVITY: **X**
NATURAL GAMMA: **X** EXTRA:
SAMPLES:

0 - 2	Topsoil, black
2 - 14	Clay, yellow-brown, silty, pebbly (till)
14 - 17	Clay, gray, silty, pebbly (till)
17 - 18	Gravel
18 - 27	Clay, gray, silty, pebbly (till)
27 - 32	Gravel
32 - 63	Clay, gray, silty, pebbly; gravel stringers (till)
63 - 109	Clay, gray, silty, pebbly (till)
109 - 166	Clay, gray, silty, sandy (lake deposit?)
166 - 174	Gravel
174 - 313	Clay, gray, silty, pebbly; much reworked shale (till)
313 - 335	Niobrara Formation

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